

すざく衛星による高銀緯フェルミ 未同定天体の系統探査

(Takahashi et al. in prep.)

第11回高宇連研究会@早稲田

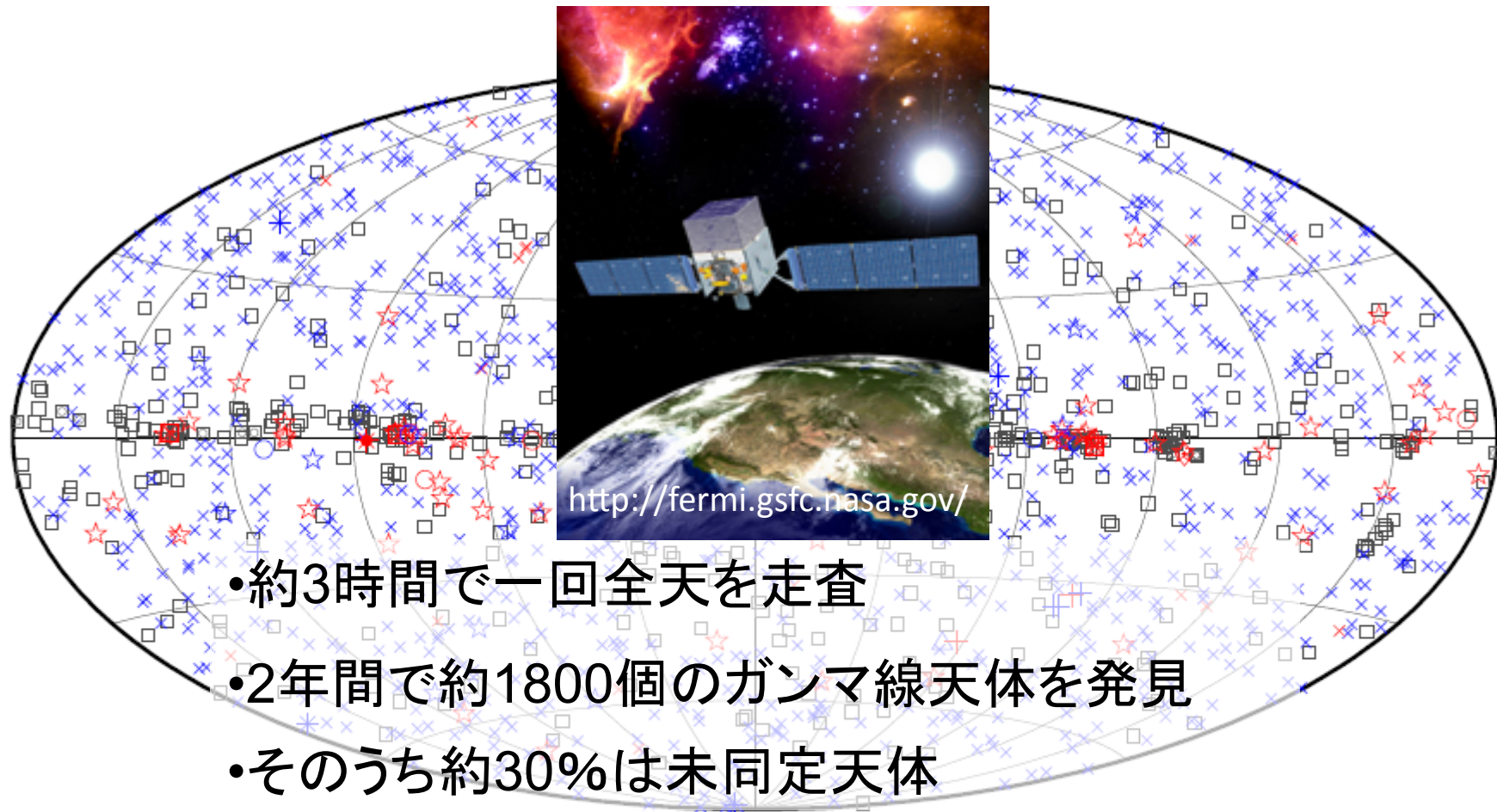
高橋洋輔 (早稲田)

片岡淳, 中森健之, 前田洸登 (早稲田), L. Stawarz,
佐藤理江, 高橋忠幸, 田中康之 (ISAS/JAXA), 真喜屋龍,
戸谷友則 (京都), 金井義和, 河合誠之 (東工大),
C.C. Cheung (NASA/GSFC), L. Guillemot, P. C. C. Freire (MPIfR),
I. Cognard (LPCE/CNRS)

Outline

1. Introduction
 1. What is unassociated sources?
 2. About our study
2. Observation results
3. Discussion
4. Conclusion

Fermi gamma-ray space telescope



□ No association	▣ Possible association with SNR or PWN	
× AGN	☆ Pulsar	△ Globular cluster
* Starburst Gal	◇ PWN	⊠ HMB
+ Galaxy	○ SNR	★ Nova

Fermi/LAT unassociated sources

Unassociated sources are sources that have no associations in other wavelength.

- The number of unassociated sources

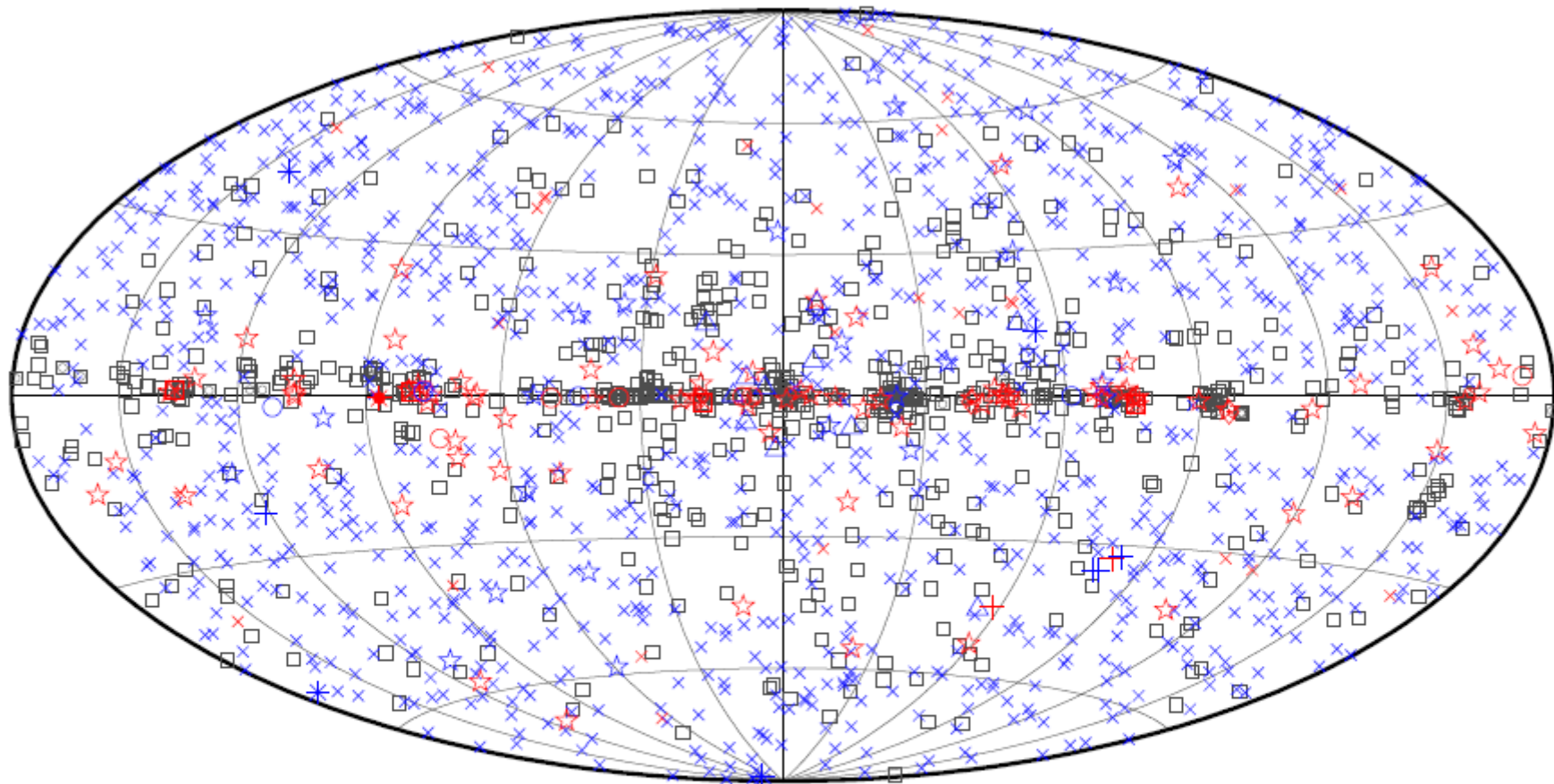
2FGL catalog – **572** out of **1873**

Many sources are still remained unassociated!

Motivation of Suzaku observation

- To survey a **new-type** gamma-ray source

Fermi gamma-ray space telescope



□ No association	▣ Possible association with SNR or PWN	
× AGN	☆ Pulsar	△ Globular cluster
* Starburst Gal	◇ PWN	⊠ HMB
+ Galaxy	○ SNR	★ Nova

2FGL catalog: Abdo et al. 2011

Introduction

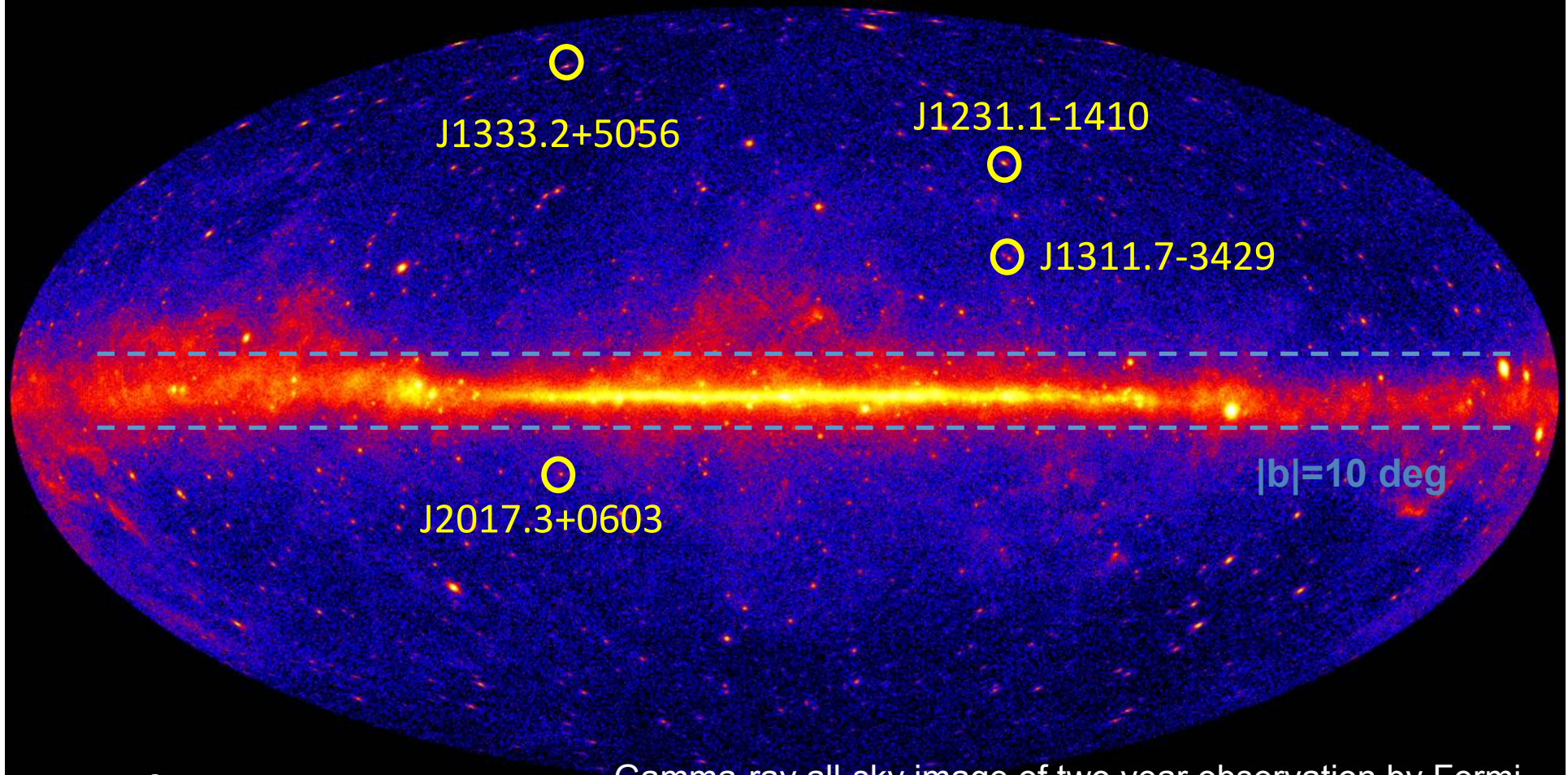
- This study is a second year campaign of X-ray follow-up observations with Suzaku.

In the first year of this campaign, we observed four unassociated sources with Suzaku.

-1FGL J1231.1-1410
-1FGL J1311.7-3429
-1FGL J1333.2+5056
-1FGL J2017.3+0603



First Year Campaign

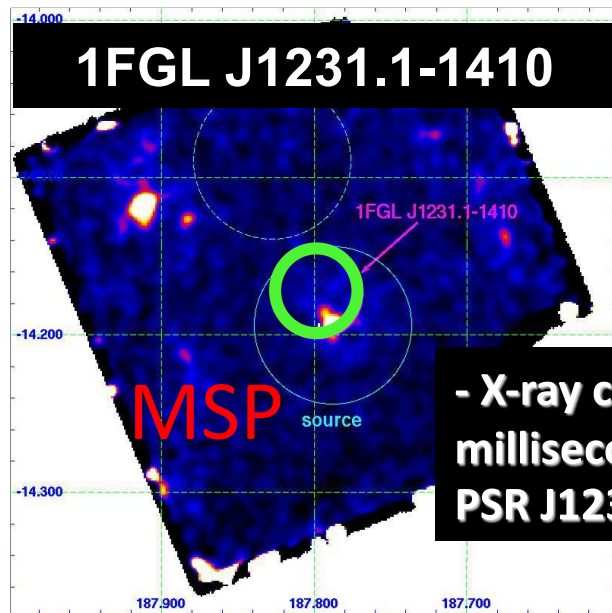


Selection Criteria

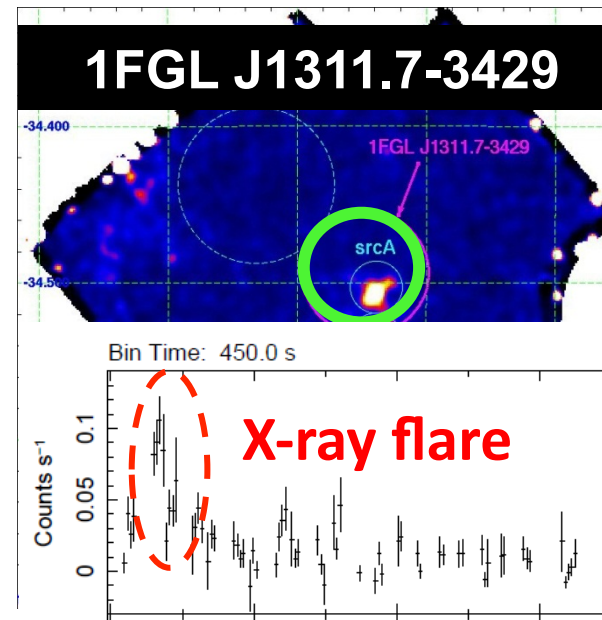
- Unassociated Objects
- More than 10 degrees away from the galactic plane
- TS value > 200

Gamma-ray all-sky image of two year observation by Fermi

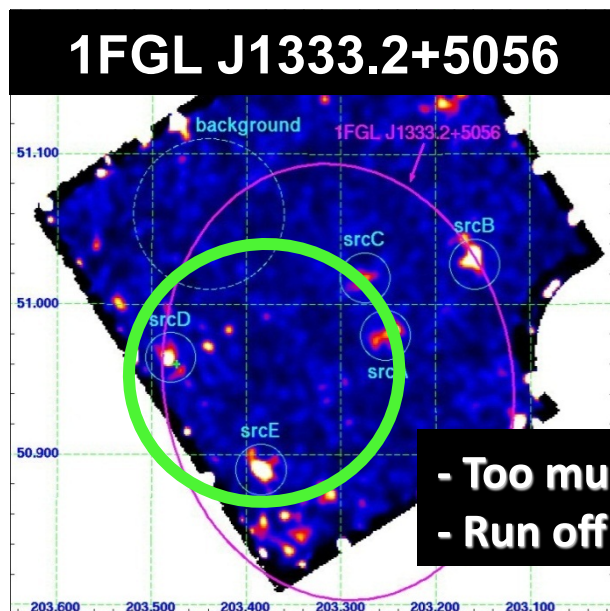
First Year Results



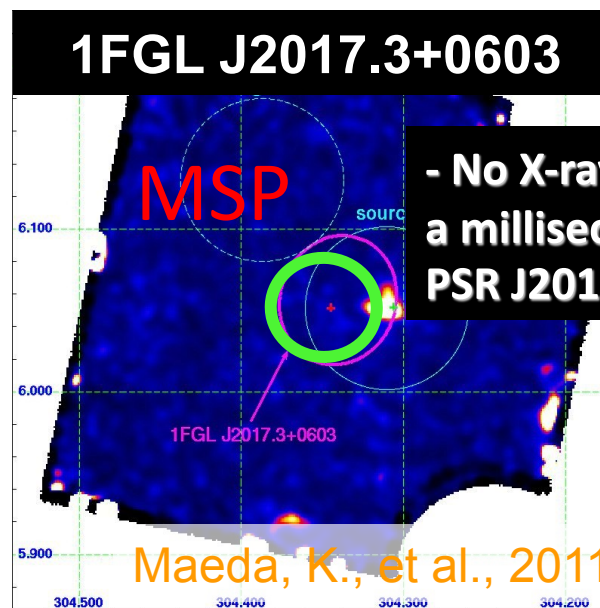
- X-ray counterpart of a millisecond pulsar PSR J1231-1411



nich



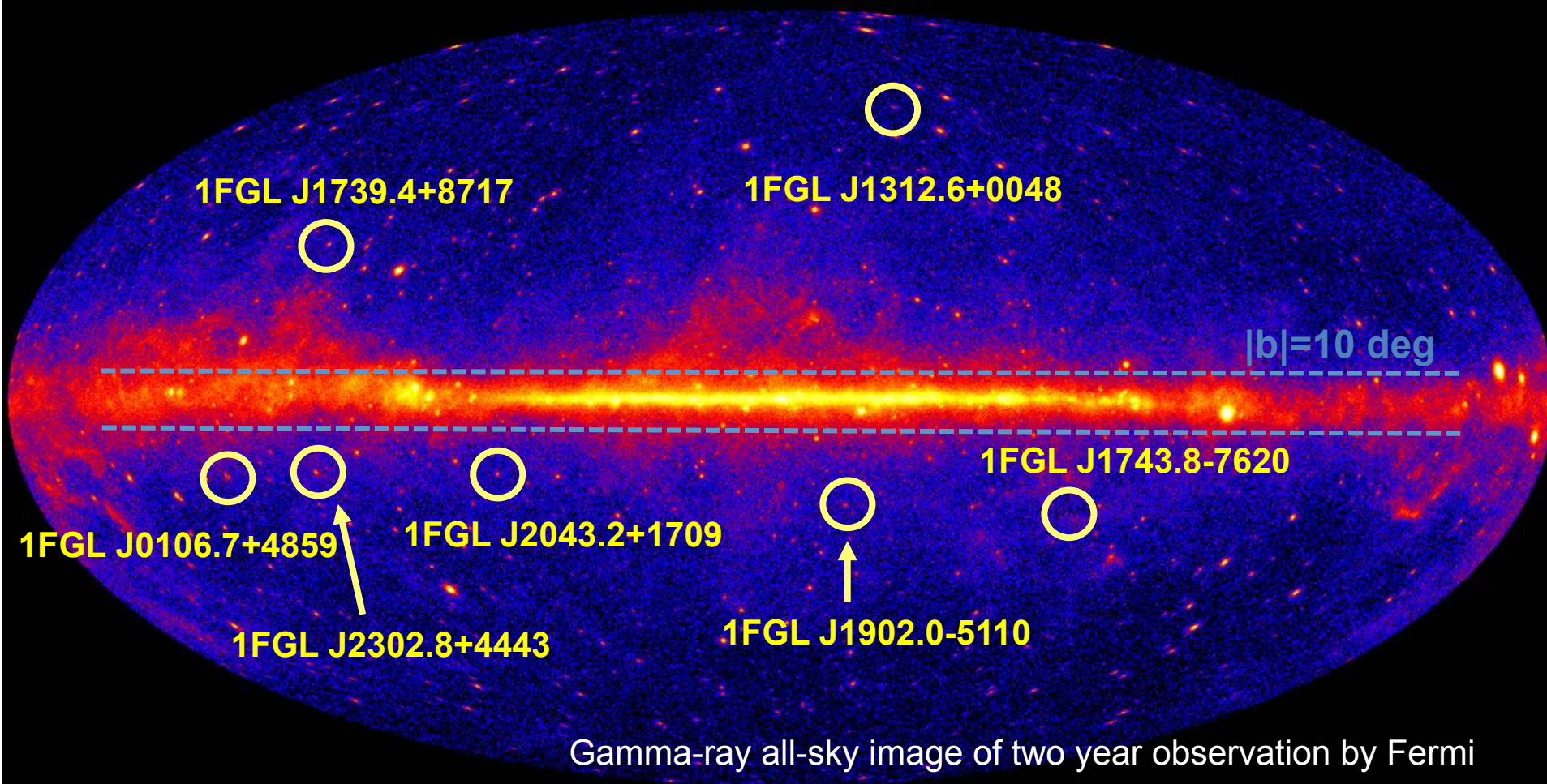
- Too much complicated
- Run off the edge of FOV

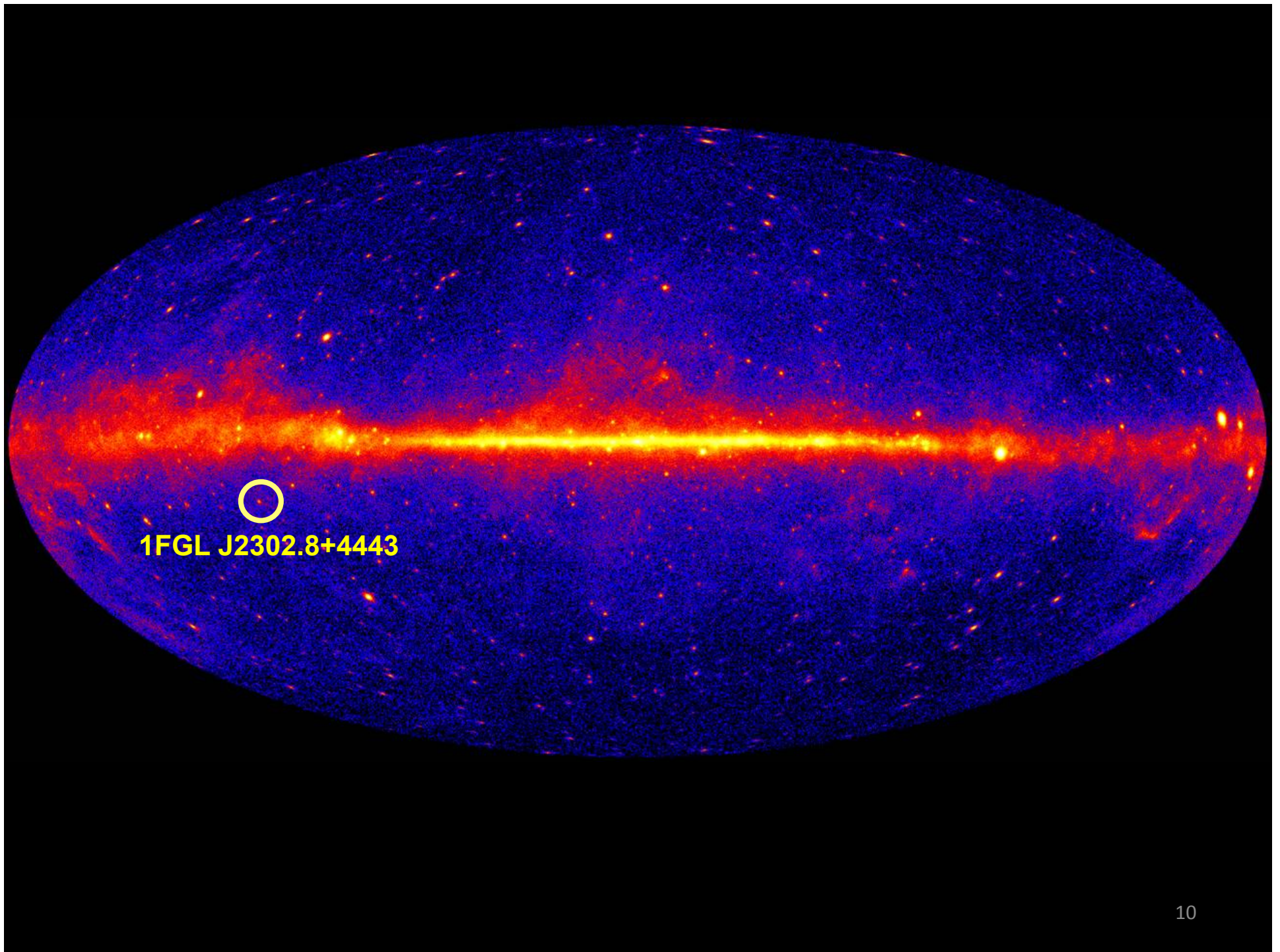


- No X-ray emission from a millisecond pulsar PSR J2017+0603

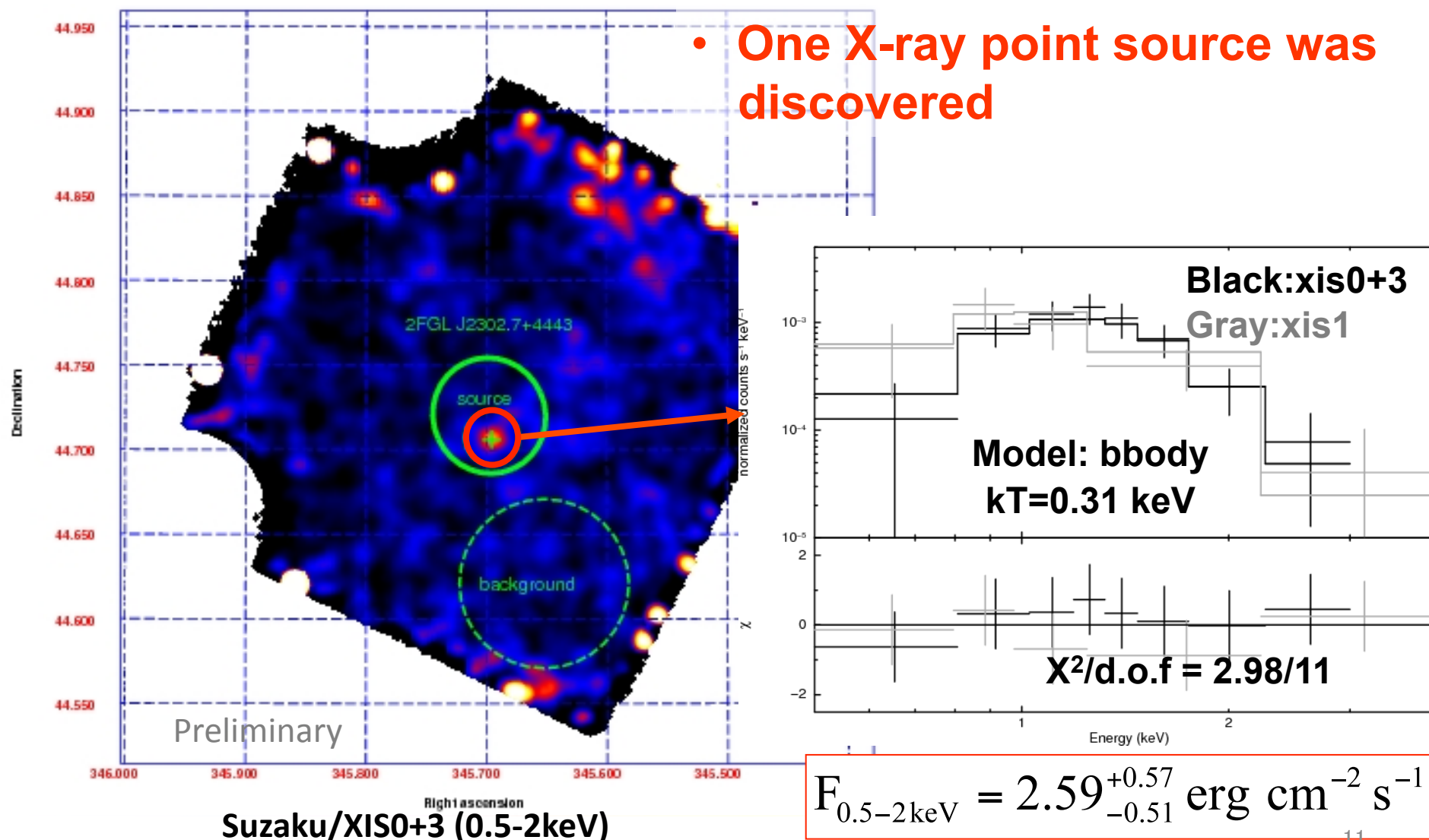
Maeda, K., et al., 2011, Apj, 729, 103

Second Year Campaign



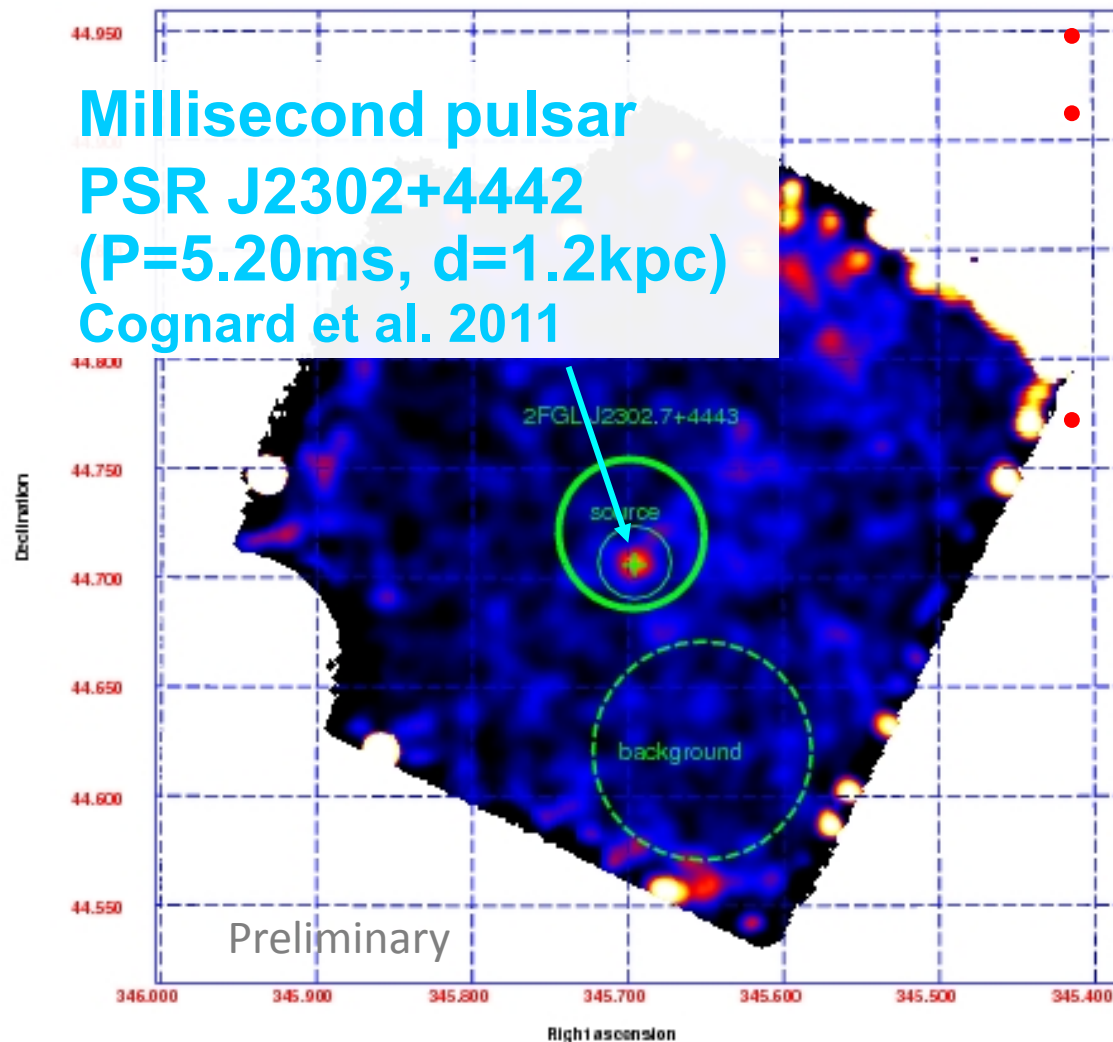


Results: 1FGL J2302.8+4443



Results: 1FGL J2302.8+4443

Millisecond pulsar
PSR J2302+4442
($P=5.20\text{ms}$, $d=1.2\text{kpc}$)
Cognard et al. 2011

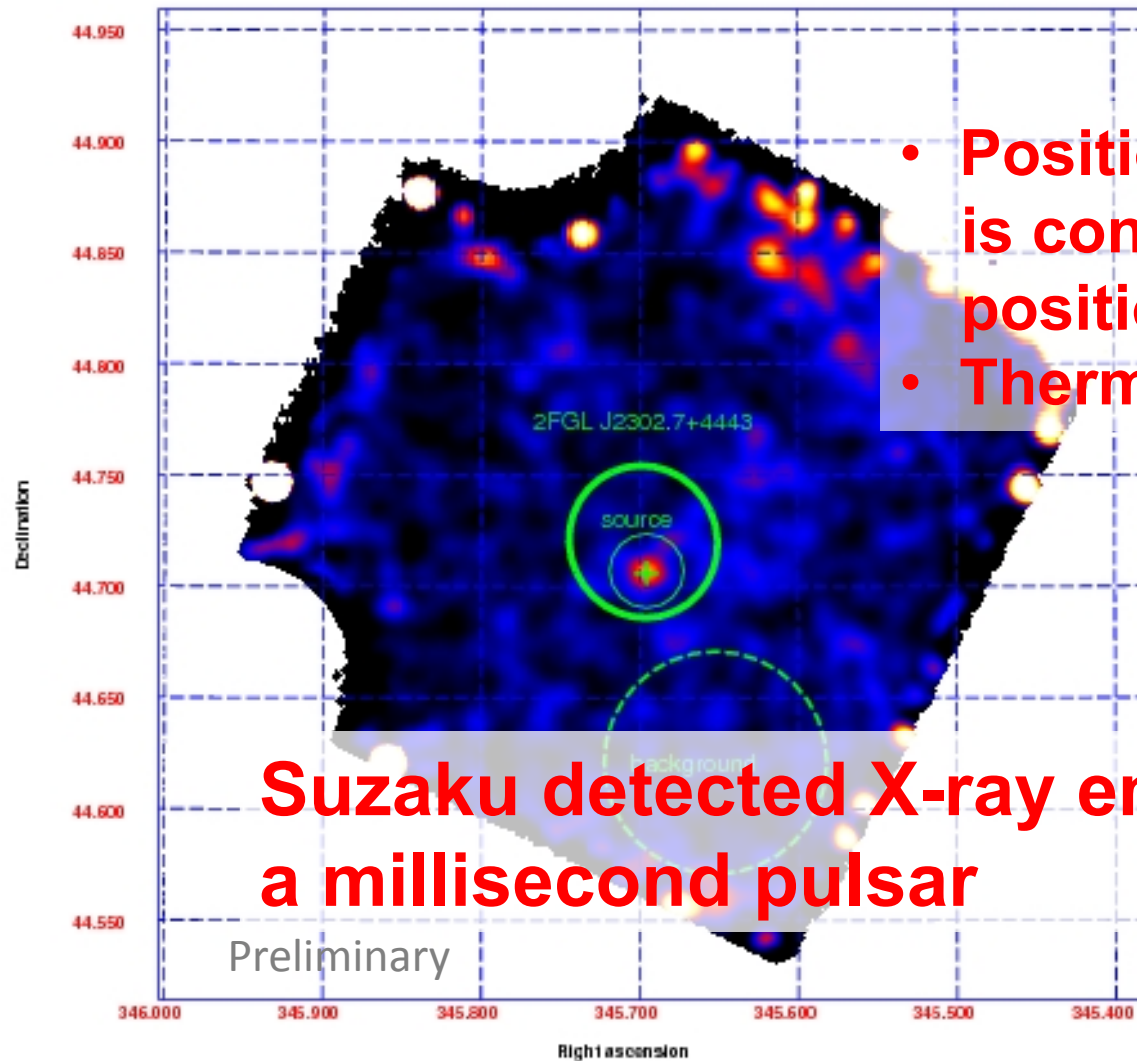


- LAT pulsations are detected
- This source is identified as a millisecond pulsar PSR J2302+4442 reported by Cognard et al. 2011
- XMM-Newton detected X-ray counterpart of MSP PSR J2302+4442

Suzaku/XIS0+3 (0.5-2keV)

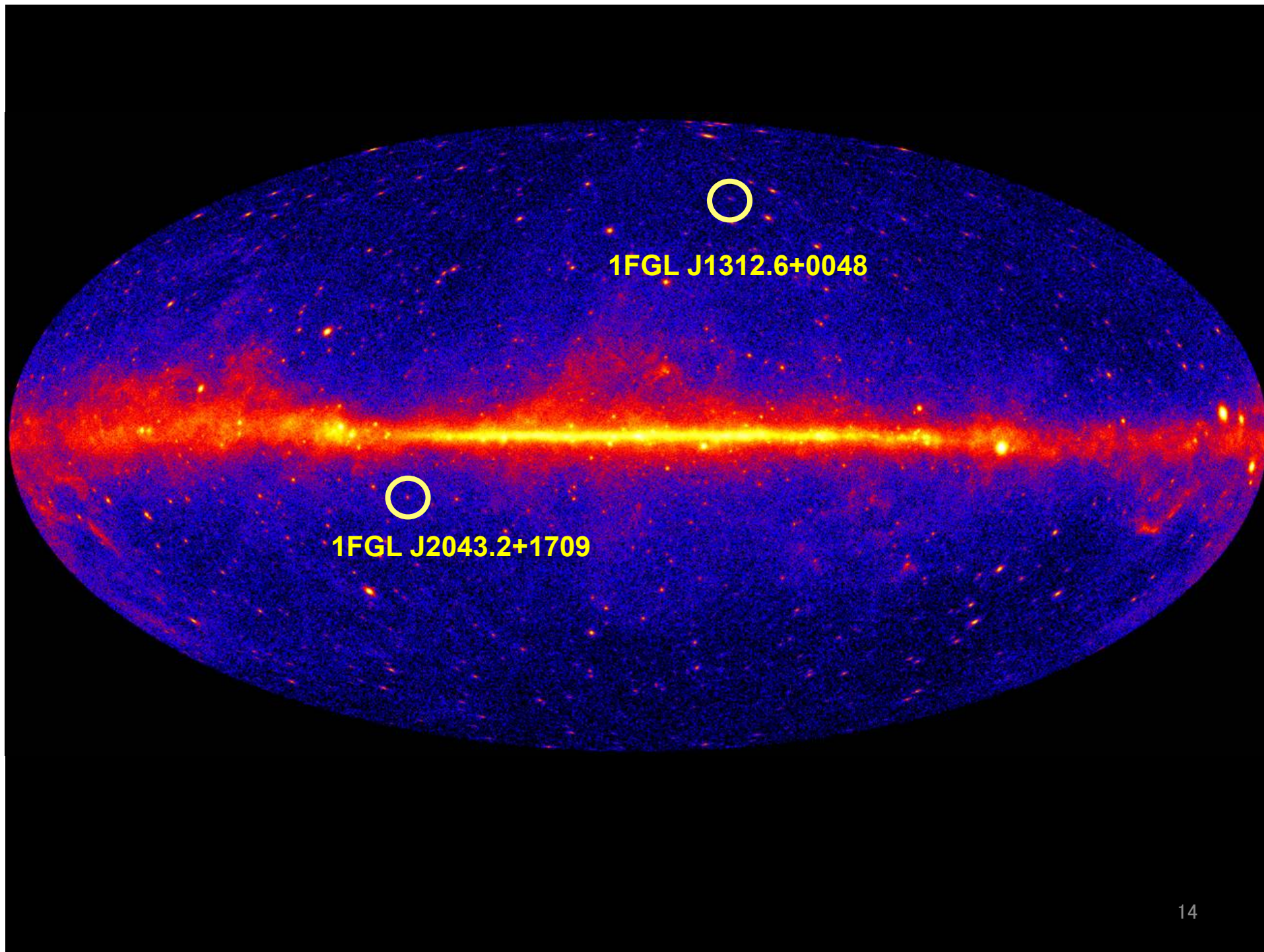
(Subtracted NXB, corrected Exposure and Vignetting)

Detection of X-ray counterpart

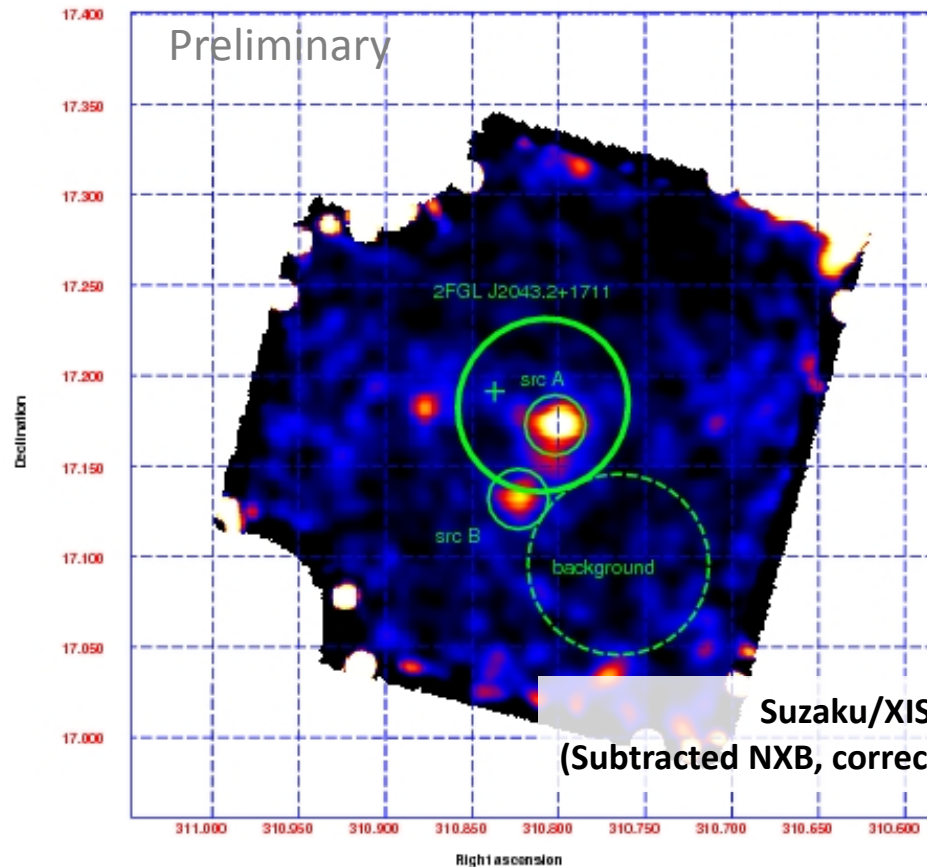


- Position of X-ray point source is consistent with a radio position of PSR J2302+44
- Thermal X-ray emission

Suzaku detected X-ray emission from a millisecond pulsar

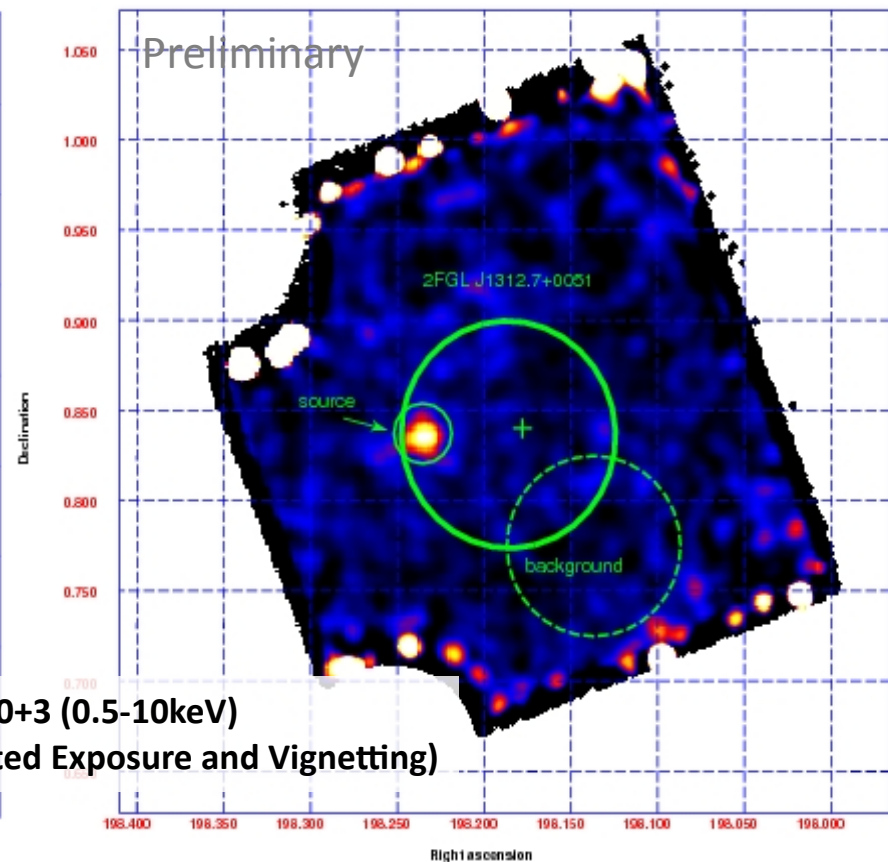


- 1FGL J2043.2+1709



- Two X-ray point sources inside the 2FGL error ellipse

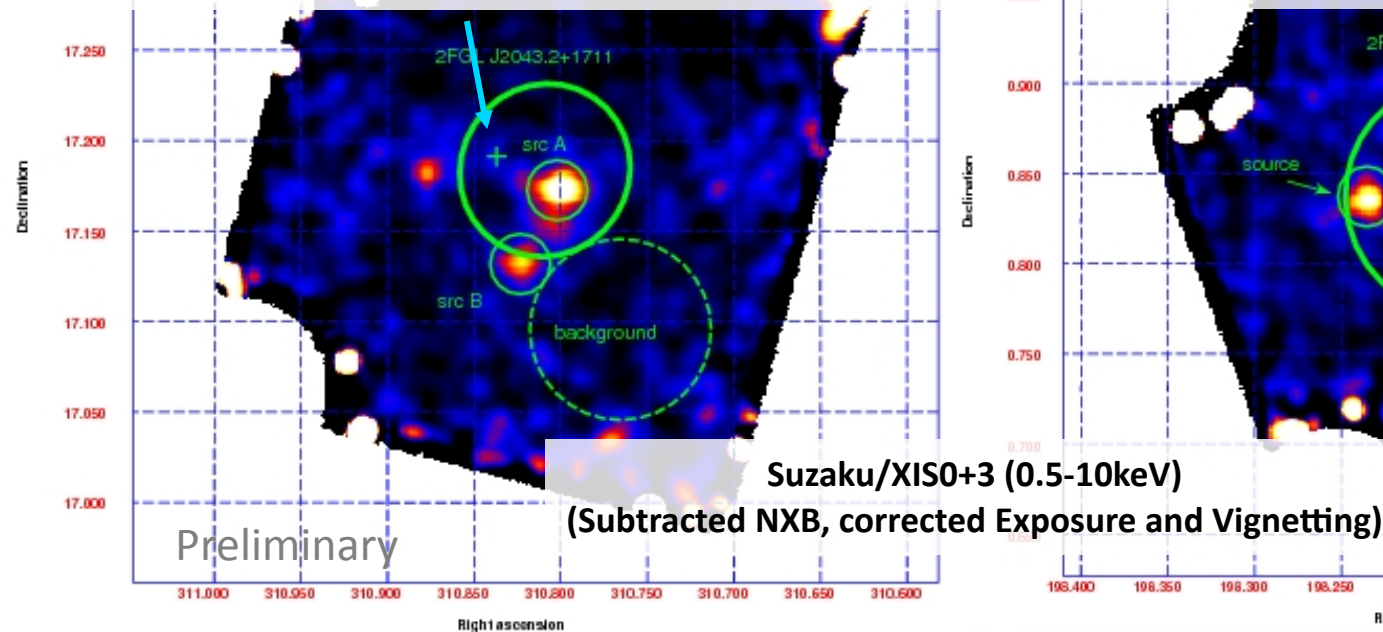
- 1FGL J1312.6+0048



- One X-ray point source was discovered inside the 2FGL error ellipse

- 1FGL J2043.2+1709

Millisecond pulsar PSR J2043+1710
($P=2.38\text{ms}$, $d=1.8\text{kpc}$)
(Guillemot et al. in prep.)

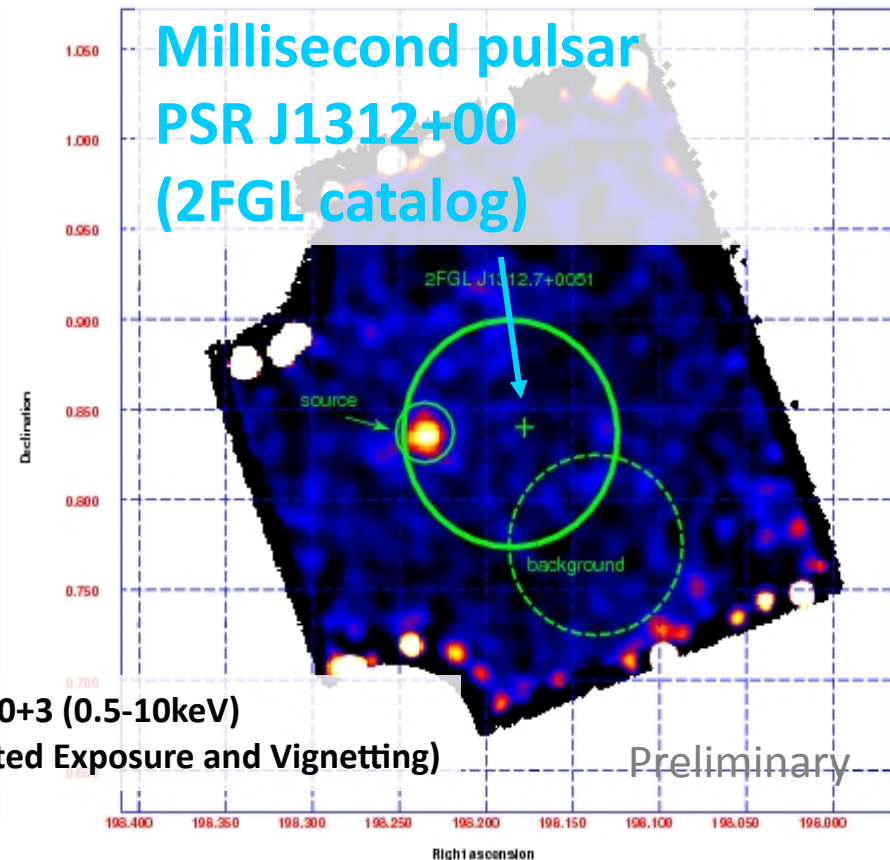


- 90% confidence upper limit for PSR J2043+1710

$$F_{2-10\text{keV}} < 3.63 \times 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}$$

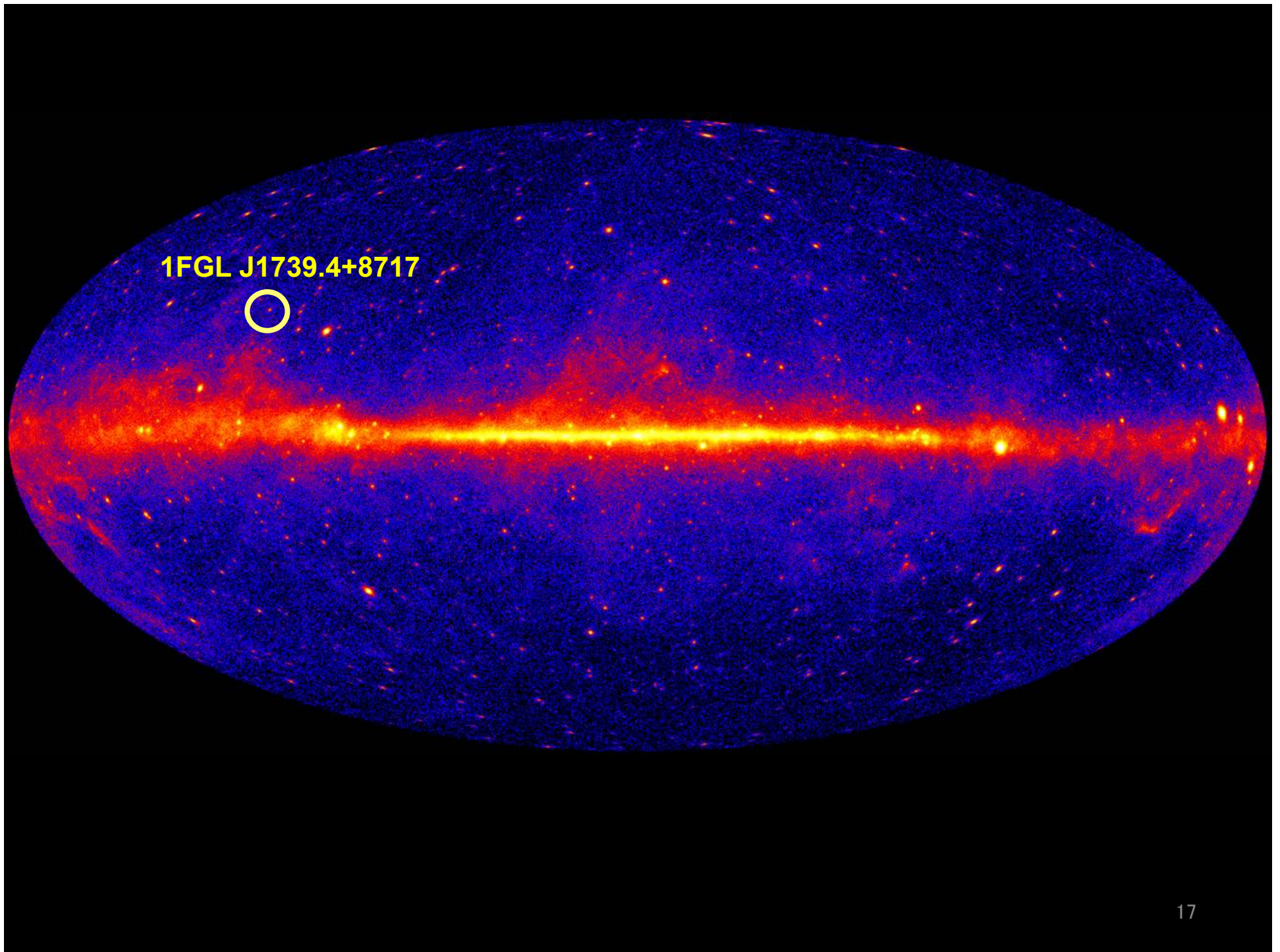
- 1FGL J1312.6+0048

Millisecond pulsar PSR J1312+00
(2FGL catalog)



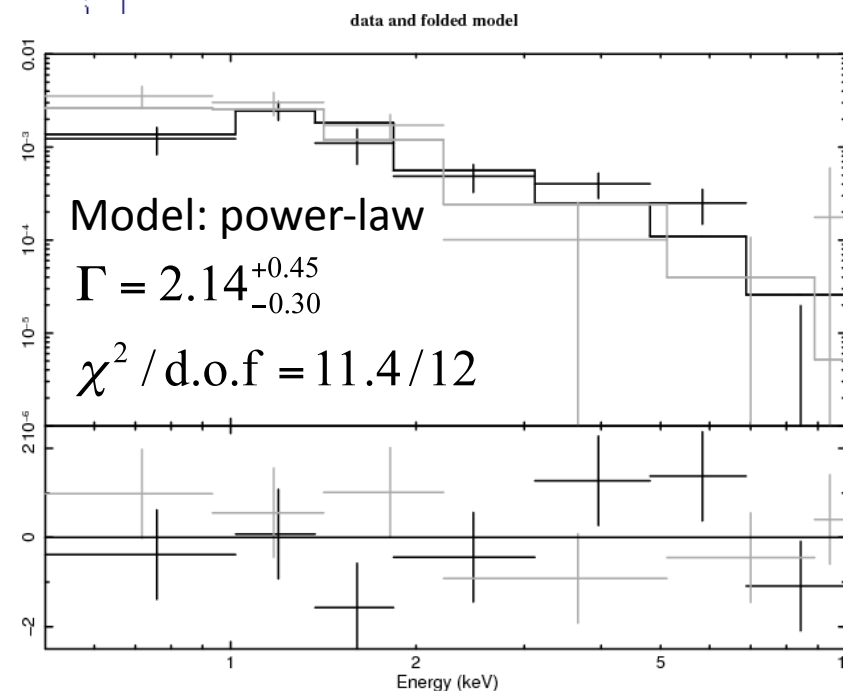
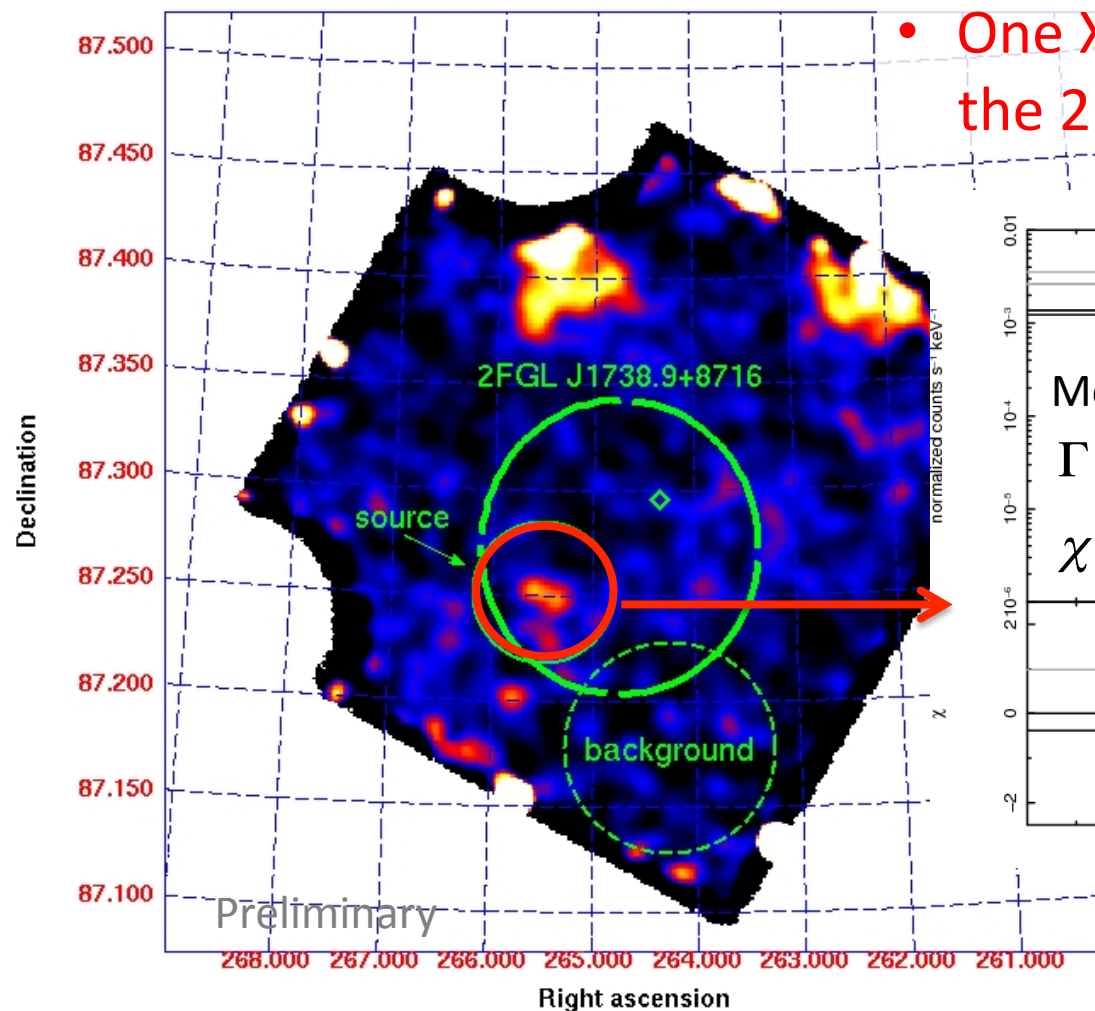
- 90% confidence upper limit for PSR J1312+00

$$F_{2-10\text{keV}} < 1.08 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$$



- 1FGL J1739.4+8717

- One X-ray source was discovered in the 2FGL error ellipse

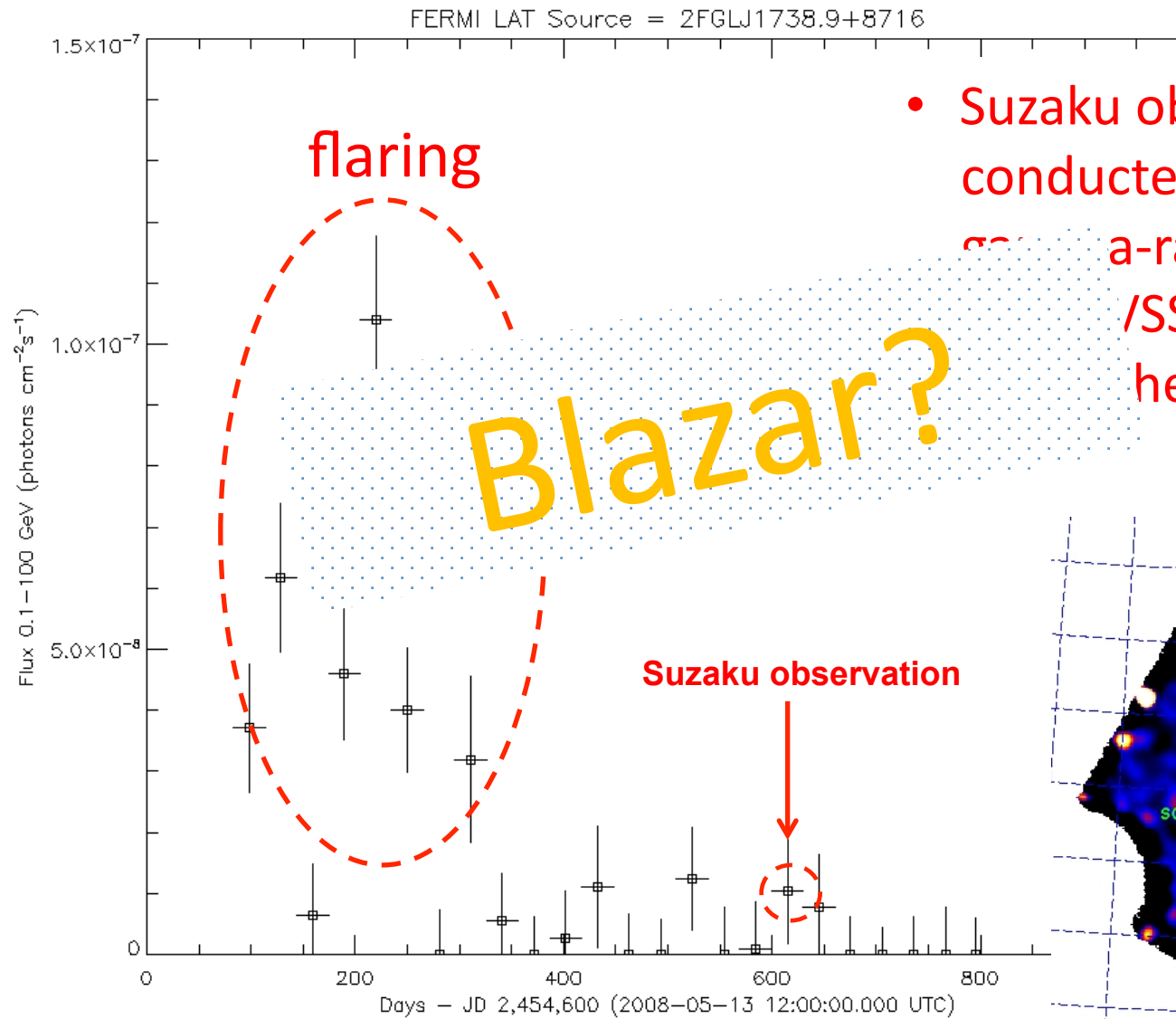


X-ray spectrum created assuming a point source

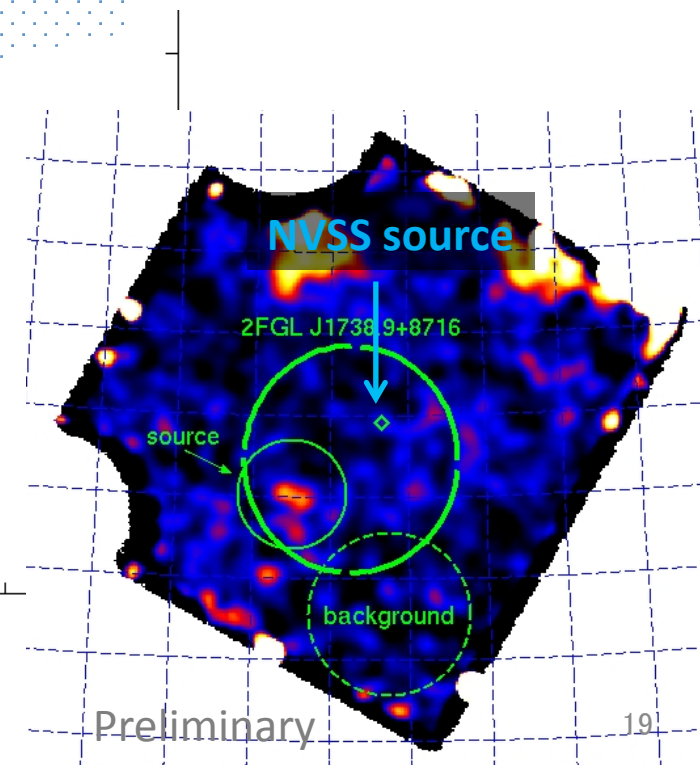
$$F_{2-10\text{keV}} = 3.58^{+1.95}_{-1.54} \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$$

Suzaku/XIS0+3 (0.5-10keV)
(Subtracted NXB, corrected Exposure and Vignetting)

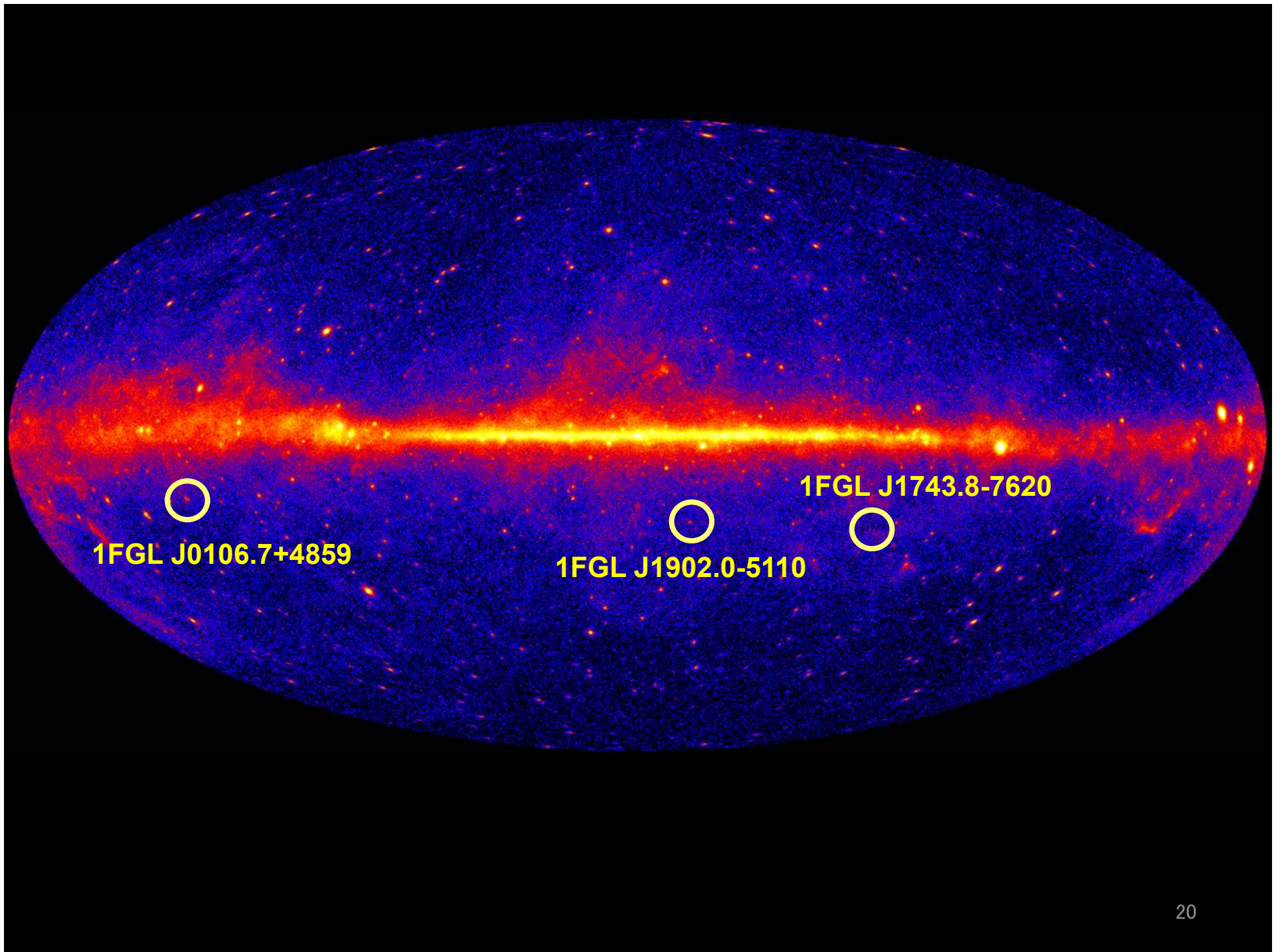
Gamma-ray flare of J1739.4



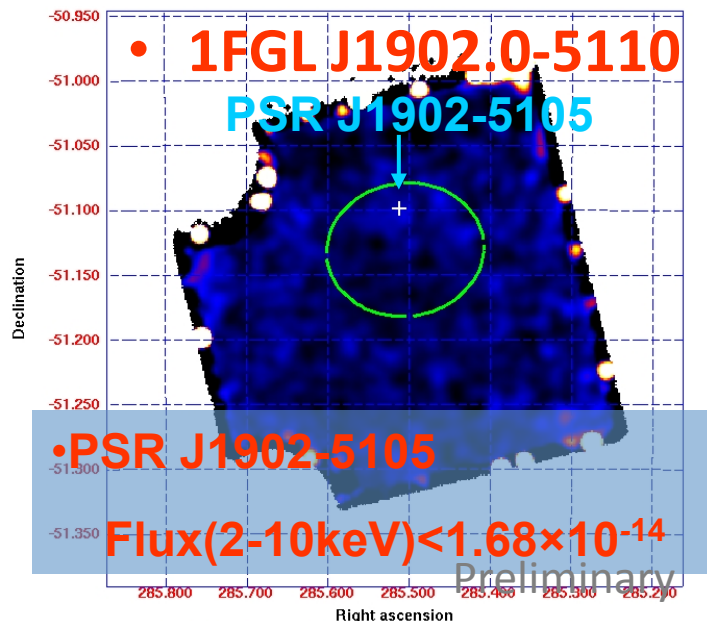
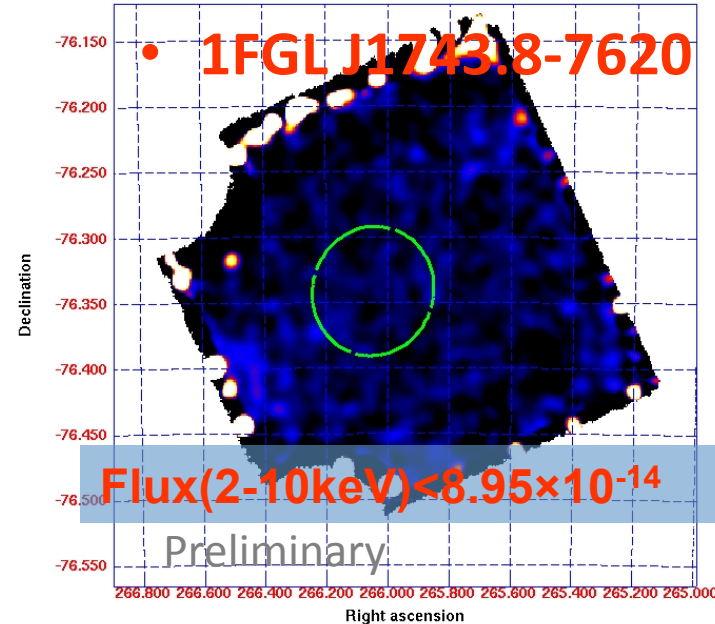
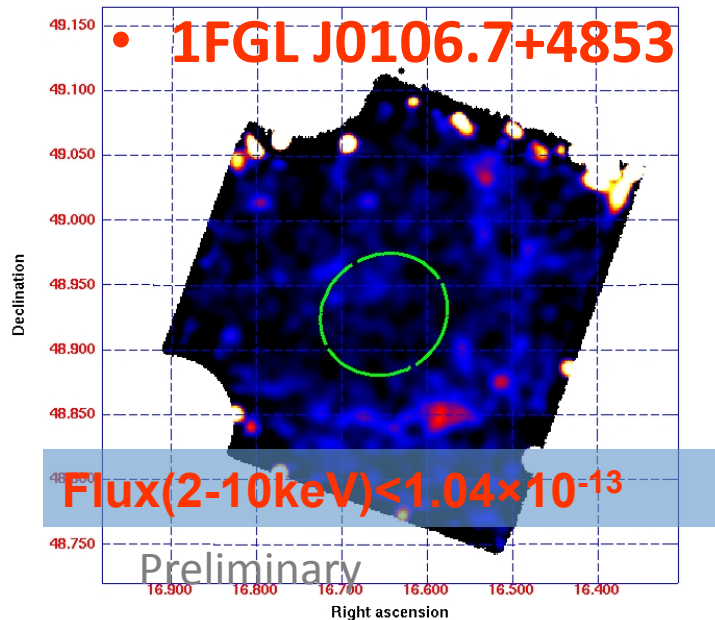
- Suzaku observation was conducted under the low γ -ray state
- NVSS source is located in the error ellipse



<http://heasarc.gsfc.nasa.gov/FTP/fermi/data/lat/catalogs/source/lightcurves/2FGLJ1738.9+8716.png>



Other three sources



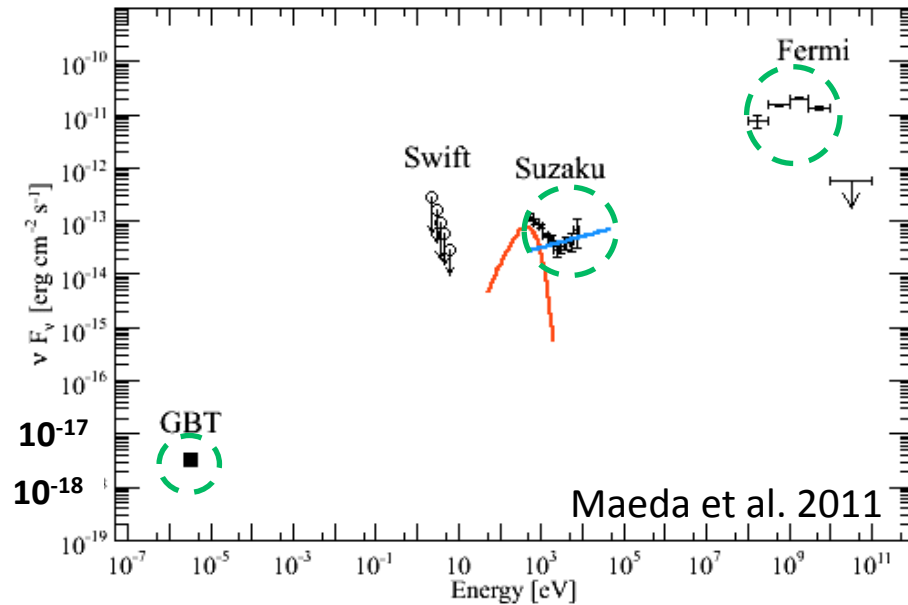
- X-ray upper limits were calculated for these three sources which Suzaku could not detect any X-ray counterparts
- 1FGL J1902.0-5110 is identified as millisecond pulsar PSR J1902-5105 and X-ray upper limit for the pulsar is presented (Ransom & Fermi Pulsar Search Consortium. 2010)

Source List

- Some of our targets have associations in 2FGL catalog

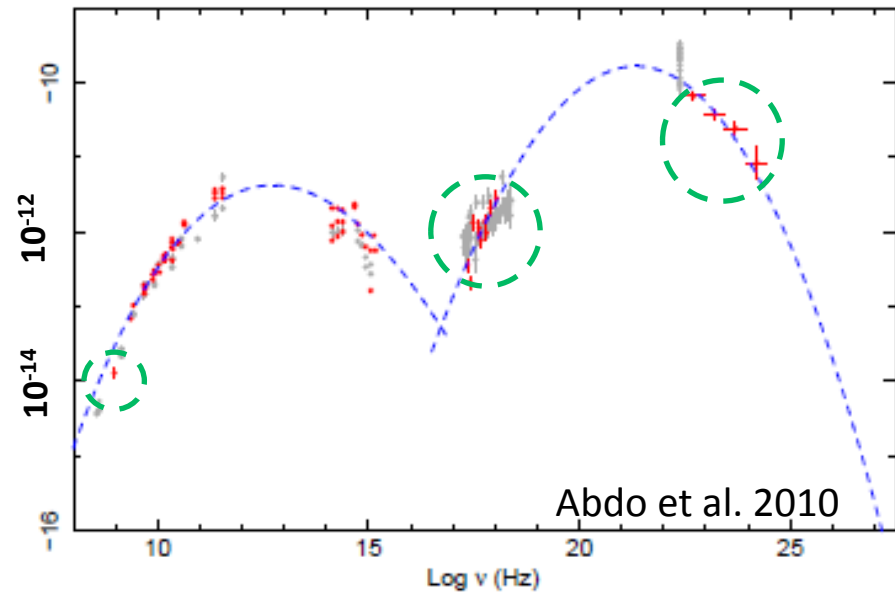
1FGL name	Association	LAT pulsation	X-ray counterpart (This work)
J0106.7+4853	No	-	No
J1312.6+0048	MSP PSR J1312+00	-	Yes (not PSR)
J1739.4+8717	No	-	Yes?
J1743.8-7620	No	-	No
J1902.0-5110	MSP PSR J1902-5105	Yes	No
J2043.2+1709	MSP PSR J2043+1710	Yes	No
J2302.8+4443	MSP PSR J2302+4442	Yes	Yes

Spectral Energy Distribution



Spectral energy distributions of a **millisecond pulsar** PSR J1231-1411

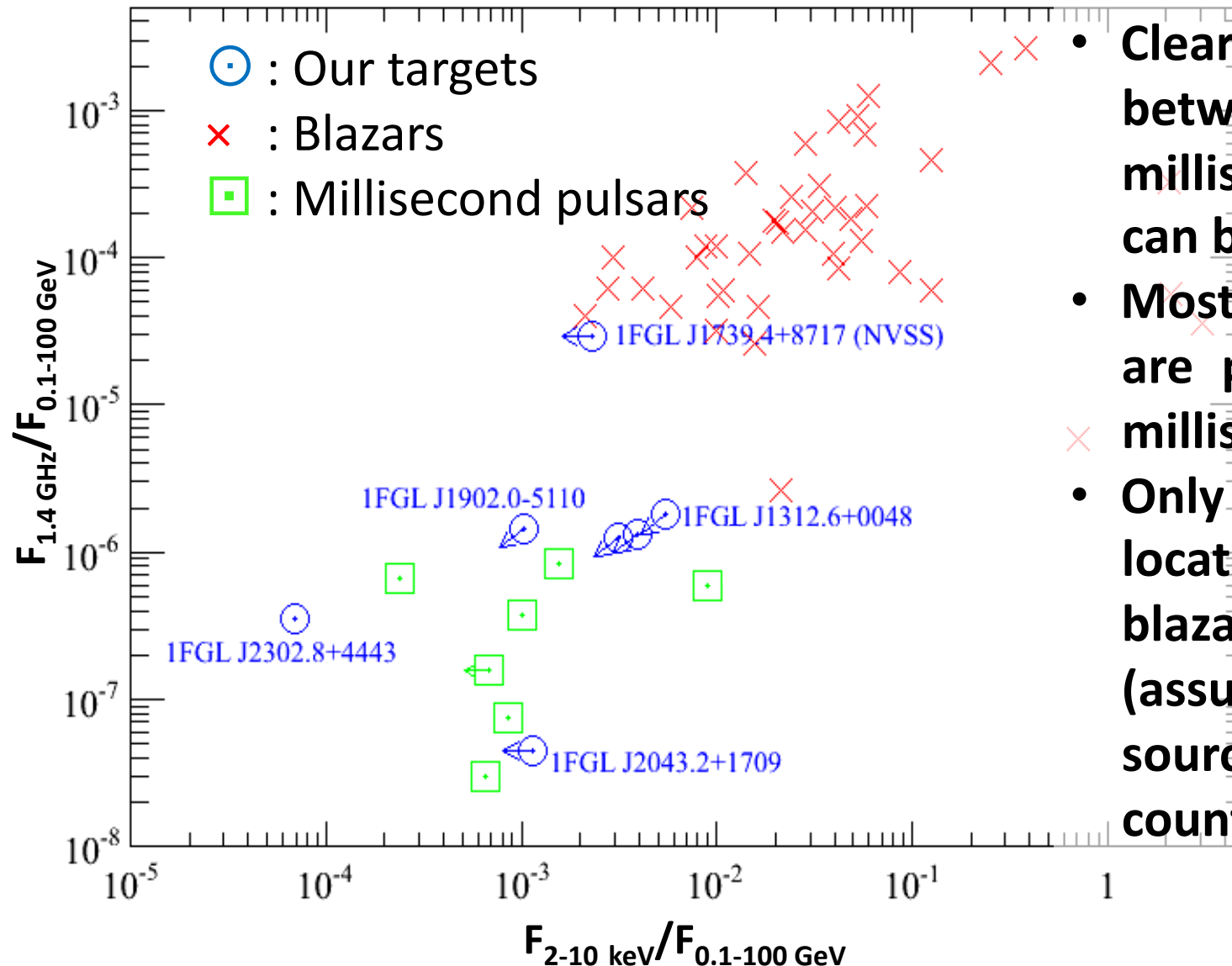
- Gamma-ray emission is far stronger compared to radio emission



Spectral energy distributions of a **blazar** PKS 0528+134

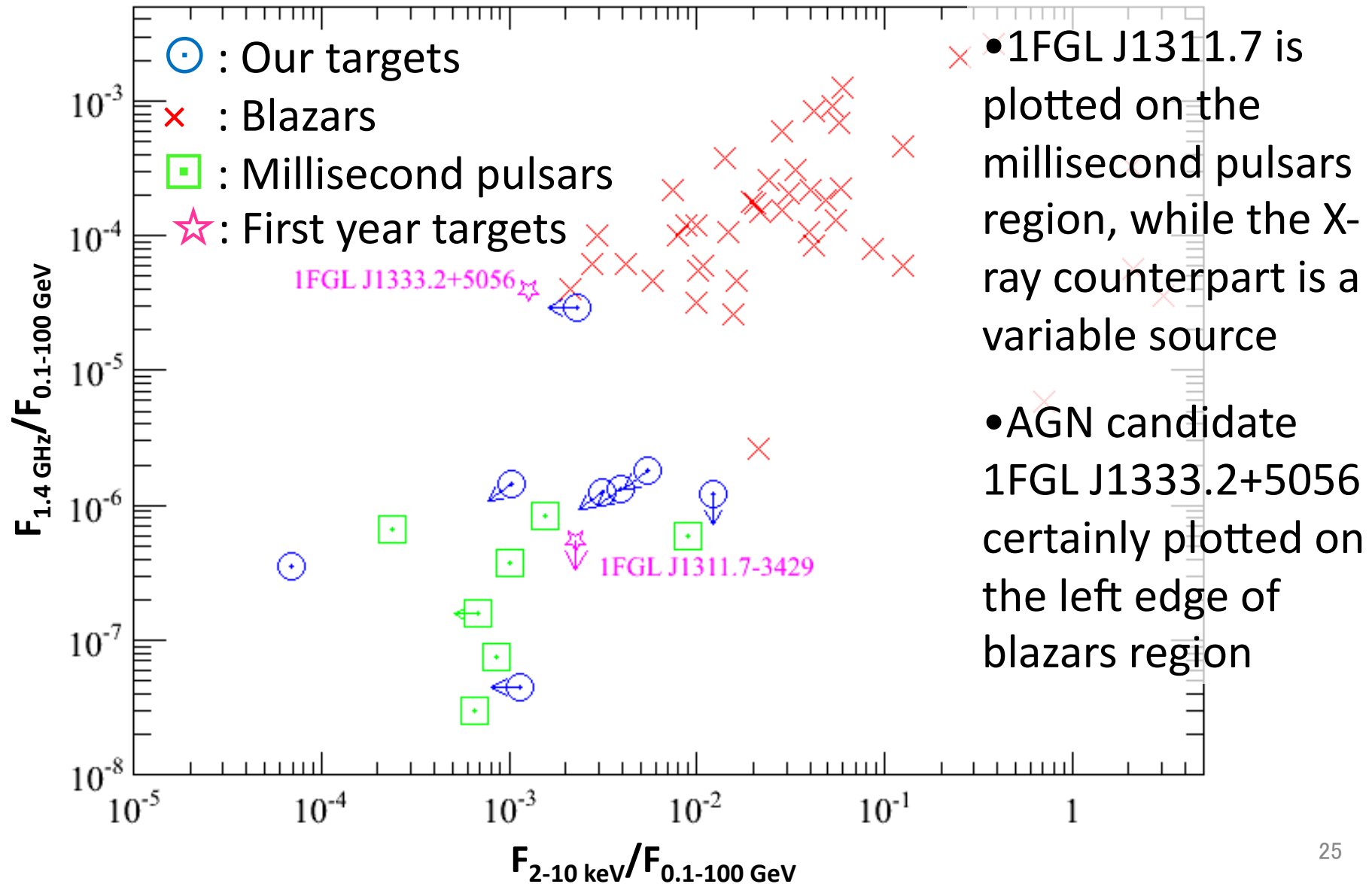
- A radio flux is only two orders of magnitude less than a gamma-ray flux

Discussion



- Clear separation between blazars and millisecond pulsars can be seen
- Most of our targets are predicted to be millisecond pulsars
- Only J1739.4 is located at the blazars region (assuming NVSS source as a radio counterpart)

Discussion



Conclusions

- Detection of X-ray counterpart to MSP PSR J2302+4442
- Millisecond pulsars are dominant objects among Fermi unassociated sources, but truly mysterious unassociated sources are still remained

Future Work

- More X-ray follow-up observations with Suzaku
 - Four observations are planned in AO-6 cycle, 1FGL J0103.1+4840, 1FGL J1311.7-3429, 1FGL J1946.7-5404, 1FGL J2339.7-0531 (PI: Kong, A., co-PI: Kataoka, J.)
- Further investigation based on multiwavelength observations

Finished



Second Year Campaign

We observed seven unassociated sources based on the eleven month of analysis.

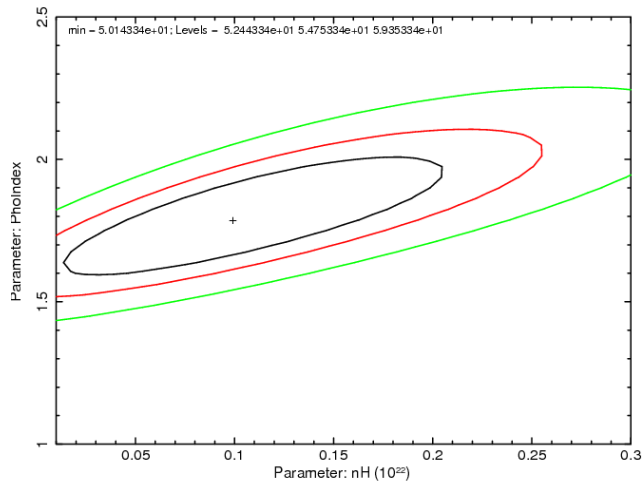
Selection Criteria

- Source name
 - **1FGL J0106.7+4853, J1312.6+0048, J1739.4+8717, J1743.8-7620, J1902.0-5110, J2043.2+1709, J2302.8+4443**
- Unassociated Objects
- More than 10 degrees away from the galactic plane
- TS value > 200

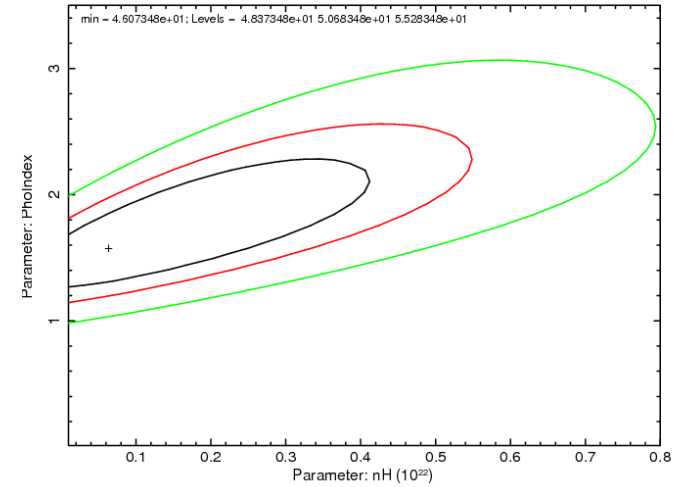
Summary

Name	X-ray		Gamma-ray F(100 MeV - 200 GeV) erg cm ⁻² s ⁻¹	Radio pulsation
	Counterpart	F(2-10keV) erg cm ⁻² s ⁻¹		
J0106.7+4853	No	$< 1.43 \times 10^{-13}$	2.42×10^{-12}	No
J1312.6+0048	Yes	8.01×10^{-13}	1.04×10^{-12}	No
J1739.4+8717	No	$< 1.11 \times 10^{-13}$	2.62×10^{-12}	No
J1743.8-7620	No	$< 8.41 \times 10^{-14}$	6.47×10^{-12}	No
J1902.0-5110	No	$< 8.13 \times 10^{-15}$ (for PSR)	5.08×10^{-12}	Yes
J2043.2+1709	No		5.78×10^{-12}	Yes
J2302.8+4443	Yes	kT = 0.31 keV	5.62×10^{-12}	Yes

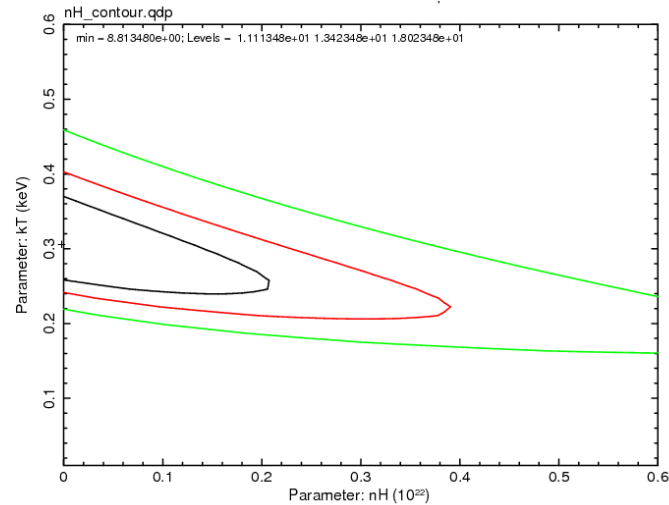
Appendix 1 - nH contour



J2043.2 source A

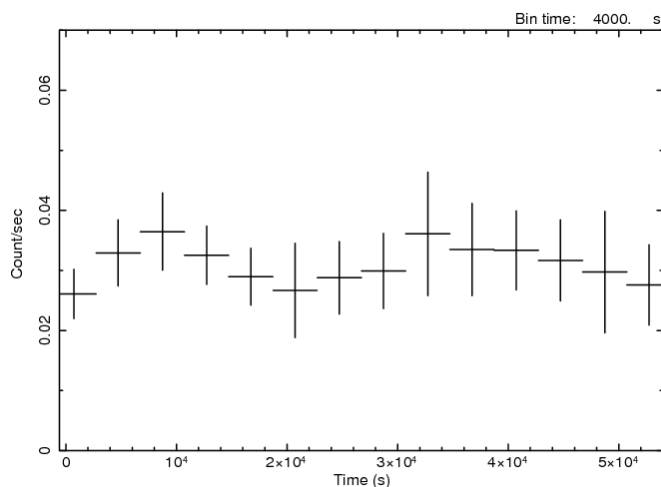


J2043.2 source B

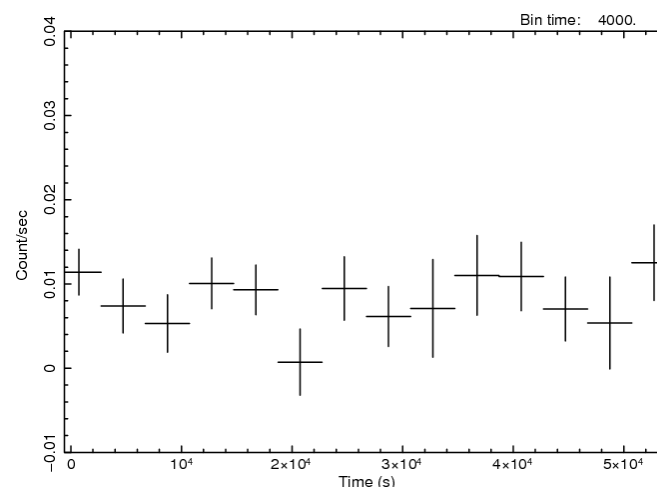


J2302.8

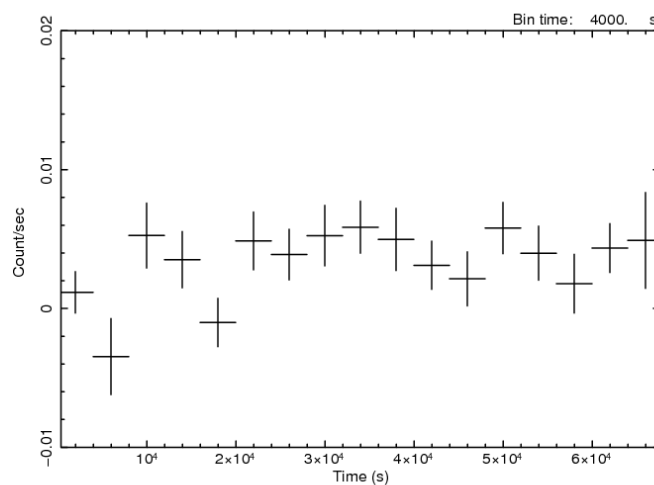
Appendix 2 – X-ray light curve (XIS0+1+3)



J2043.2 source A



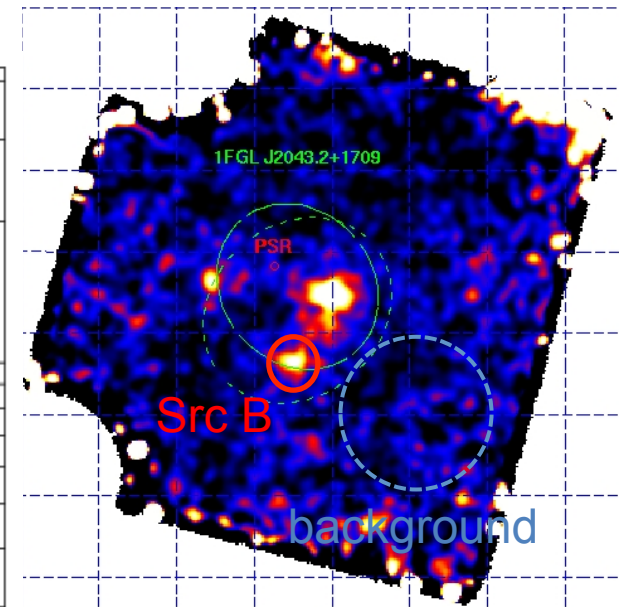
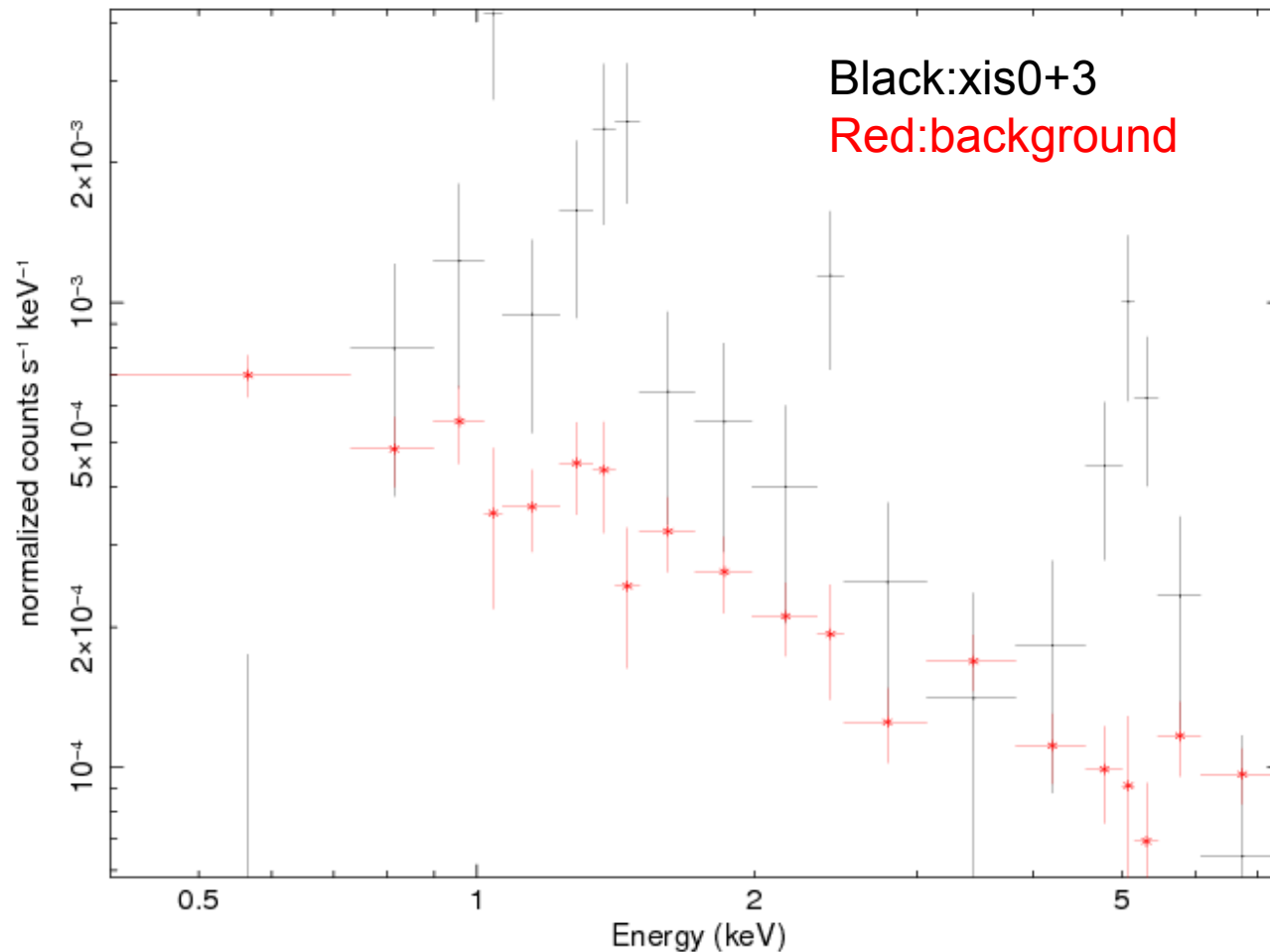
J2043.2 source B



J2302.8

Appendix 3 – J2043.2 source B

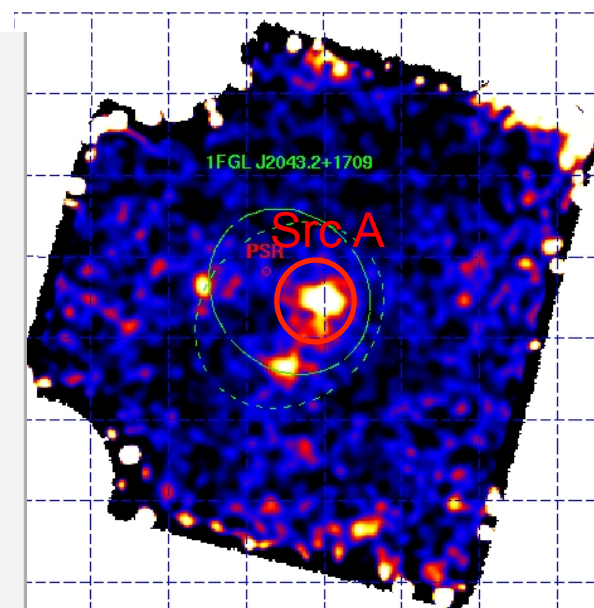
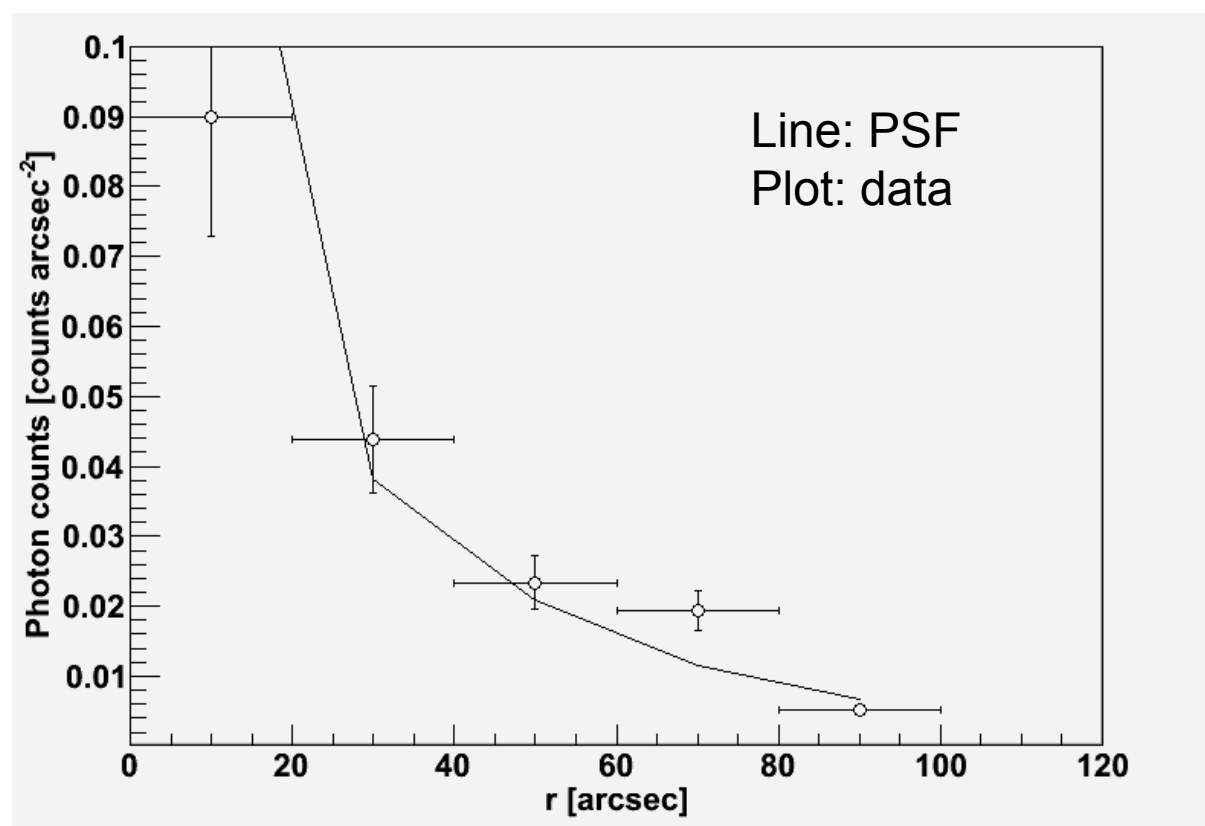
Spectrum of source B with background



A peak around 5 keV is not seen on the background spectrum.

Appendix 5 – Radial profile for source A of J2043.2

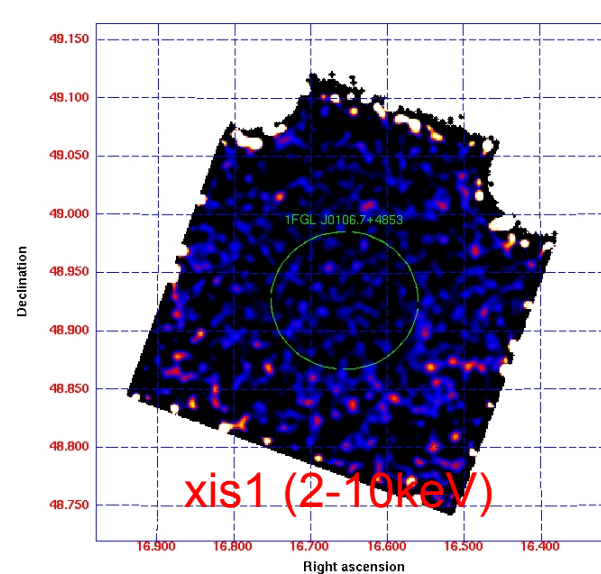
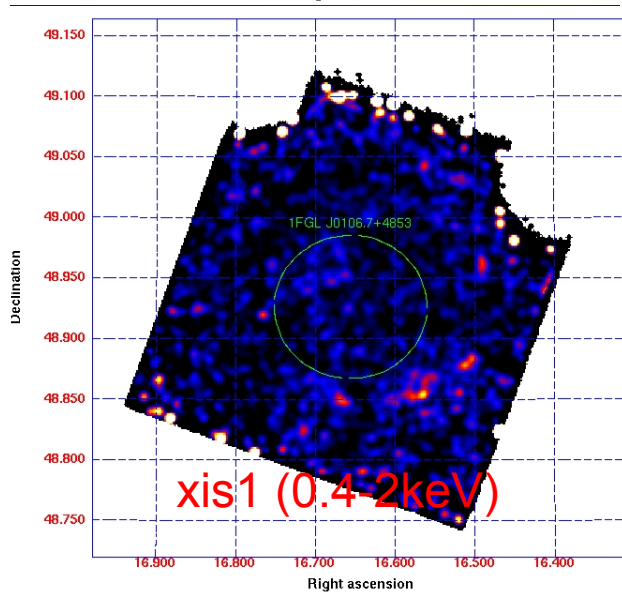
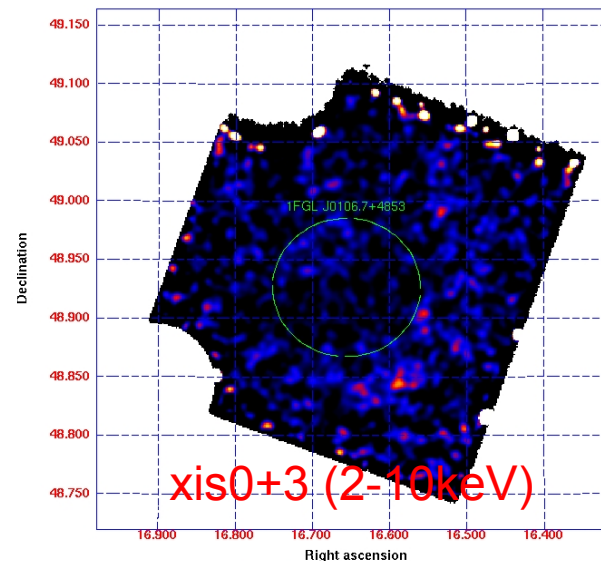
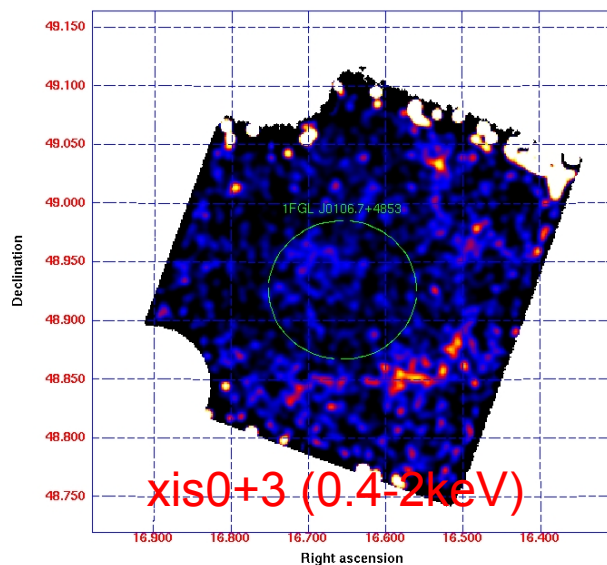
- Photon counts vs r (Distance from the center of the source)



Appendix 6 – Suzaku images

(Subtracted NXB, corrected Exposure and Vignetting)

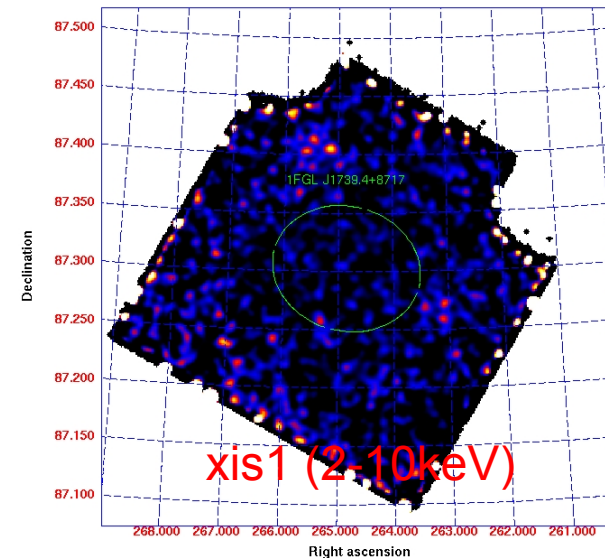
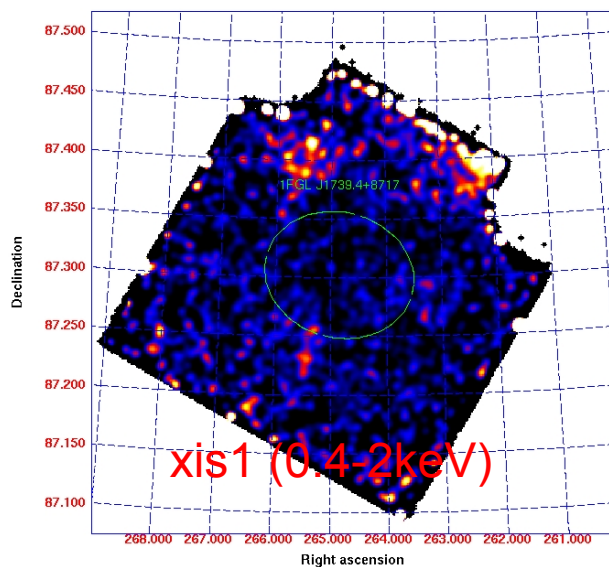
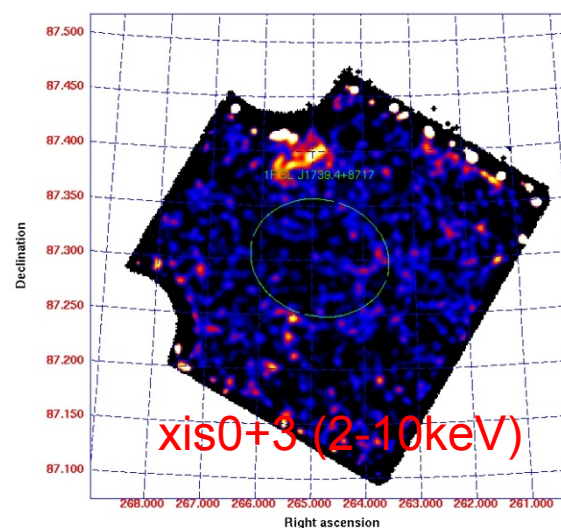
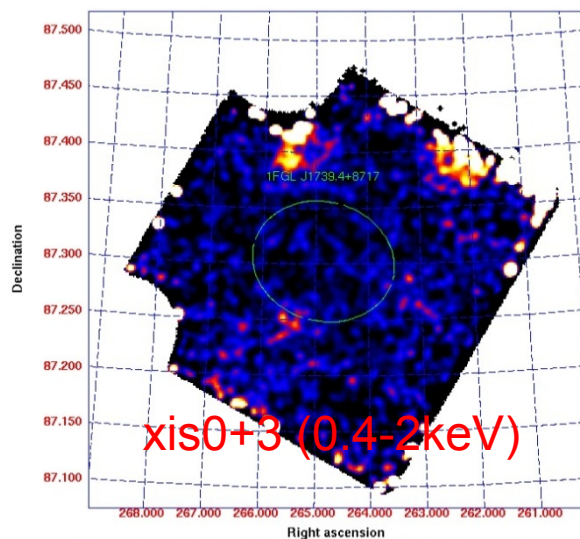
1FGL J0106.7+4853



Appendix 6 – Suzaku images

(Subtracted NXB, corrected Exposure and Vignetting)

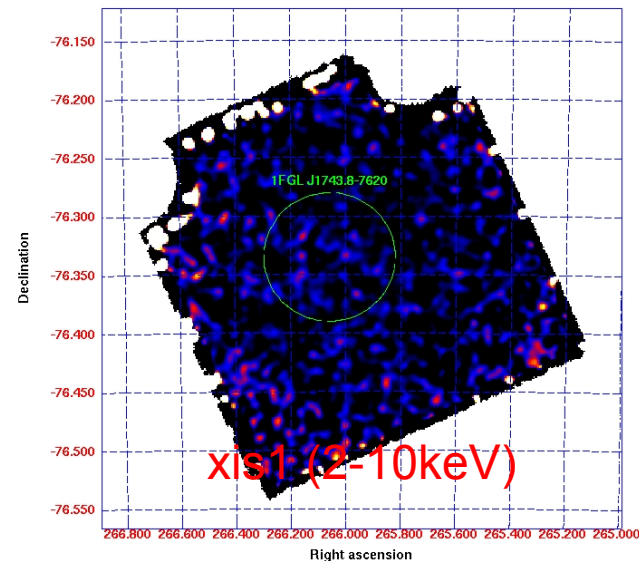
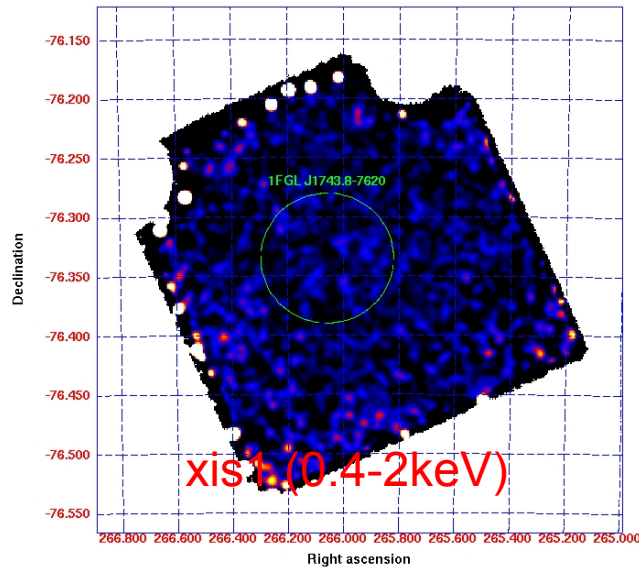
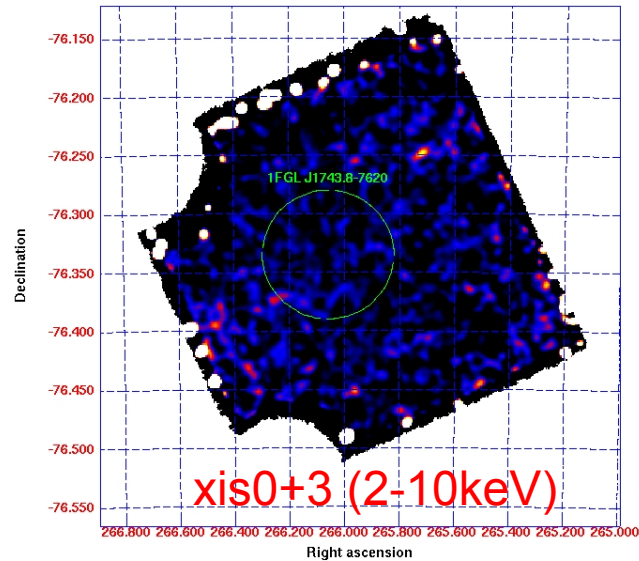
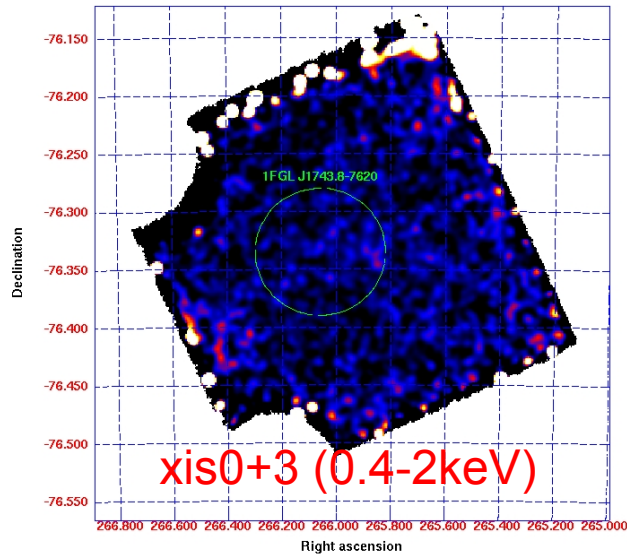
1FGL J1739.4+8717



Appendix 6 – Suzaku images

(Subtracted NXB, corrected Exposure and Vignetting)

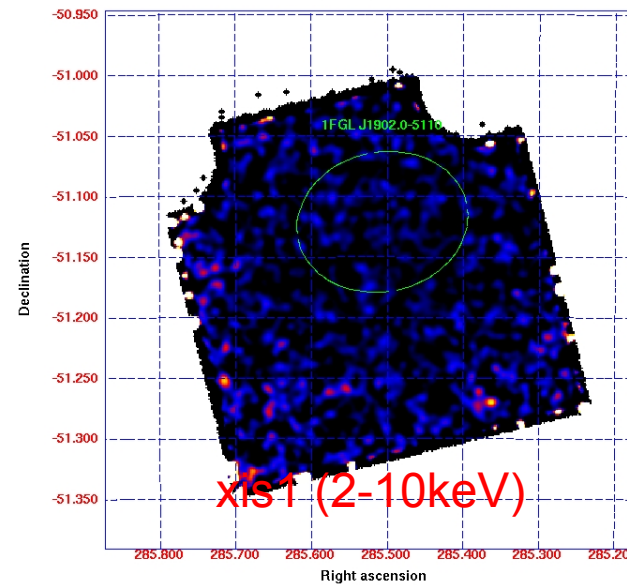
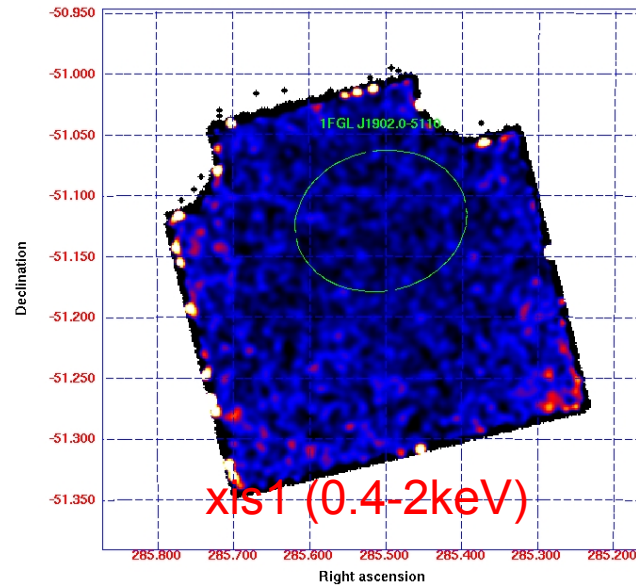
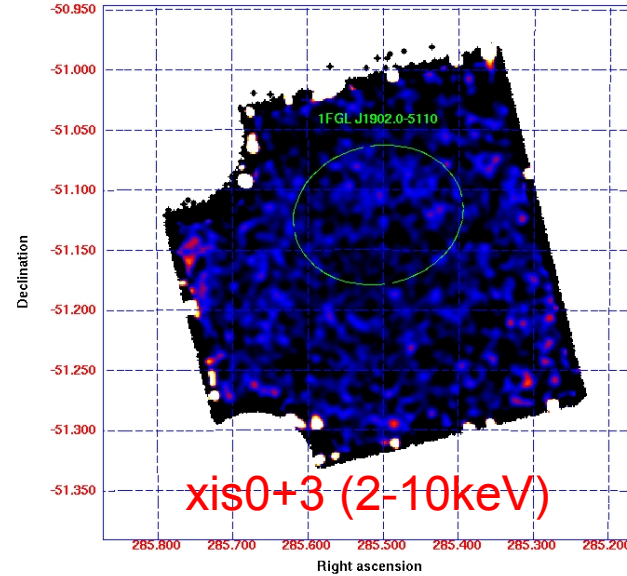
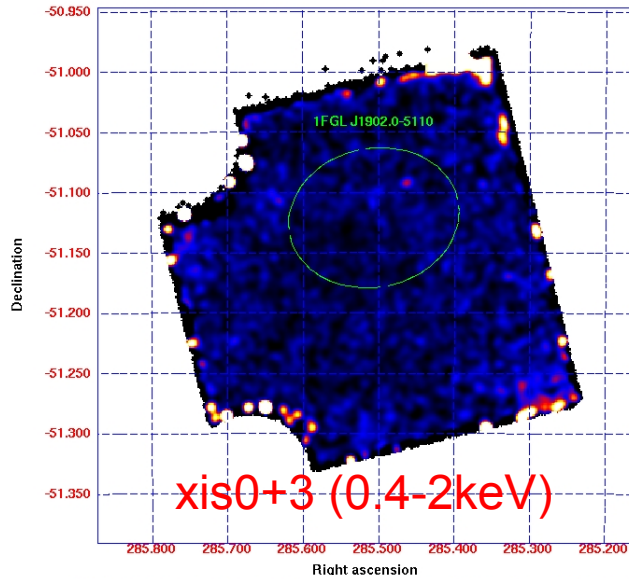
1FGL J1743.8-7620



Appendix 6 – Suzaku images

(Subtracted NXB, corrected Exposure and Vignetting)

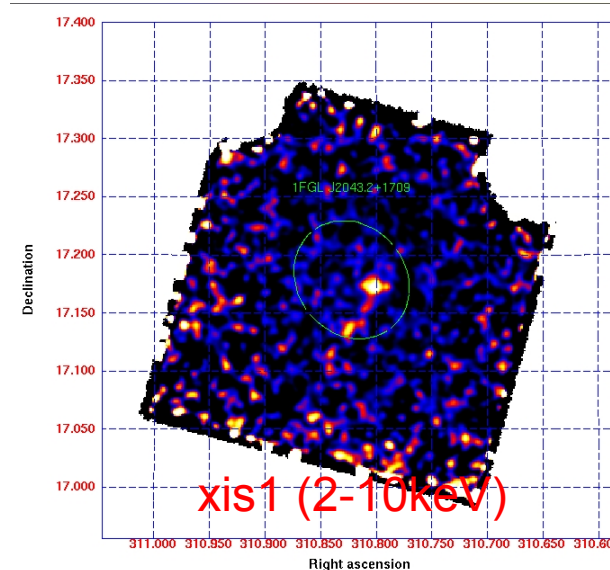
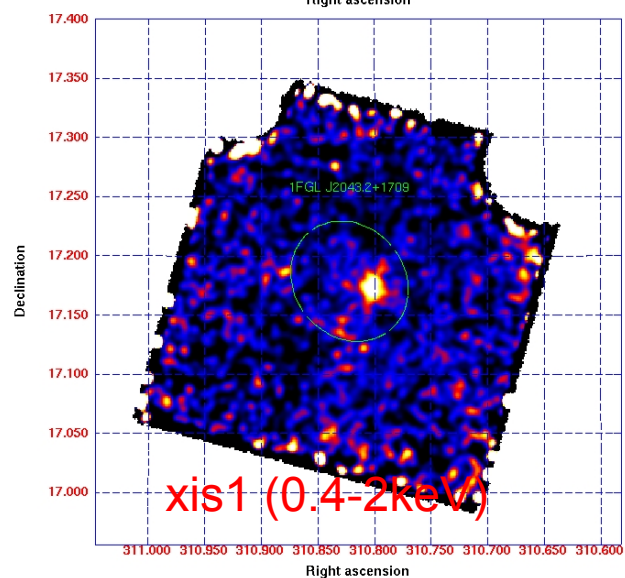
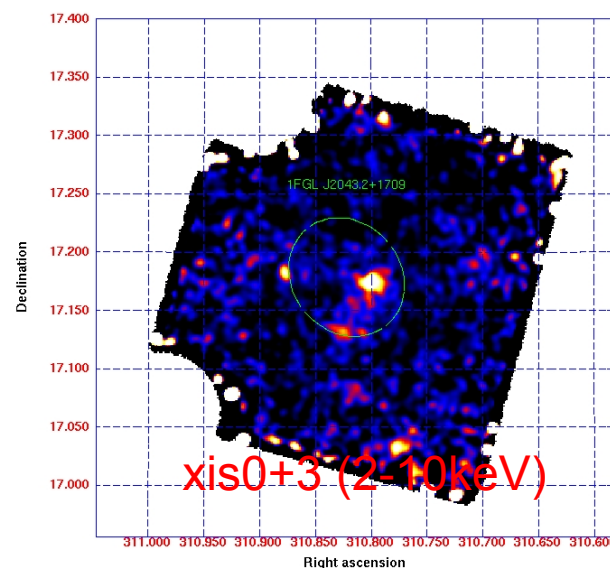
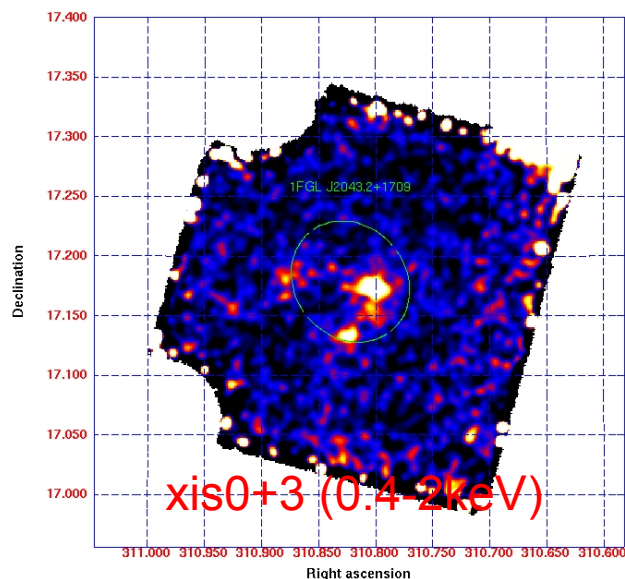
1FGL J1902.0-5110



Appendix 6 – Suzaku images

(Subtracted NXB, corrected Exposure and Vignetting)

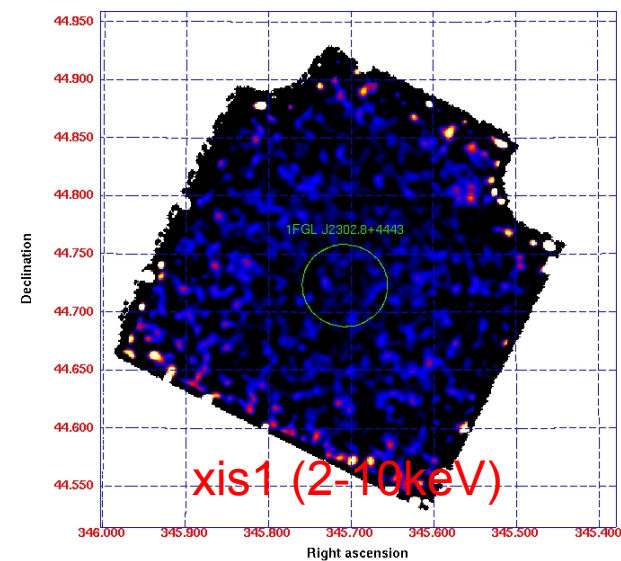
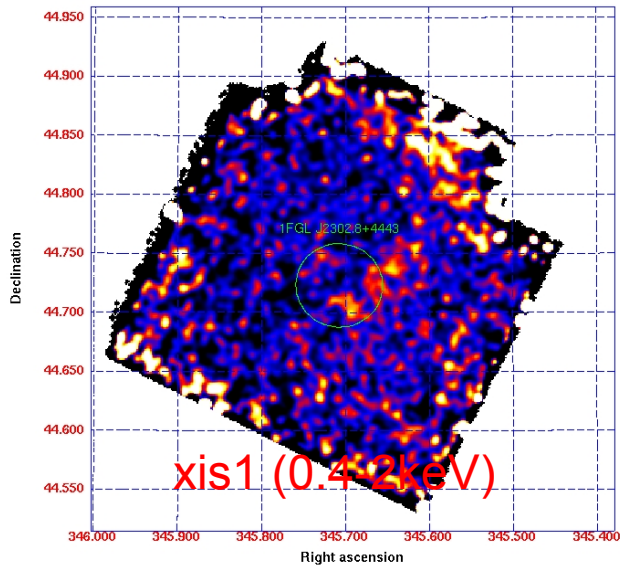
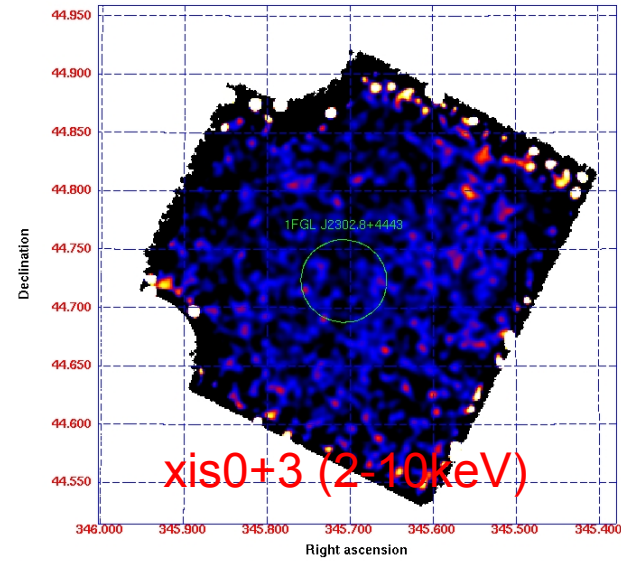
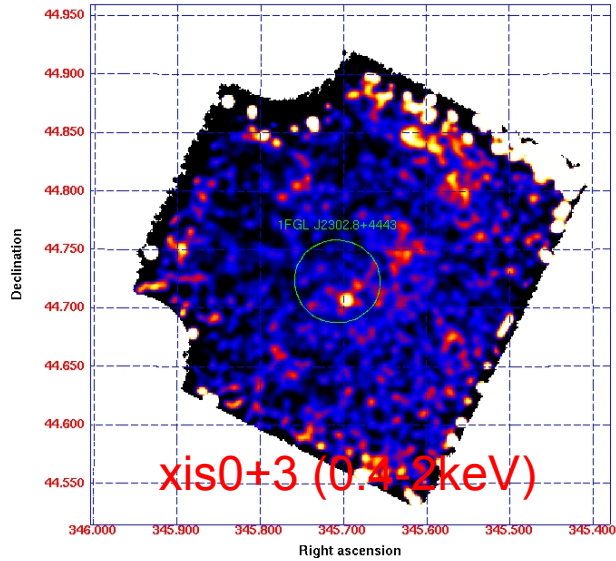
1FGL J2043.2+1709



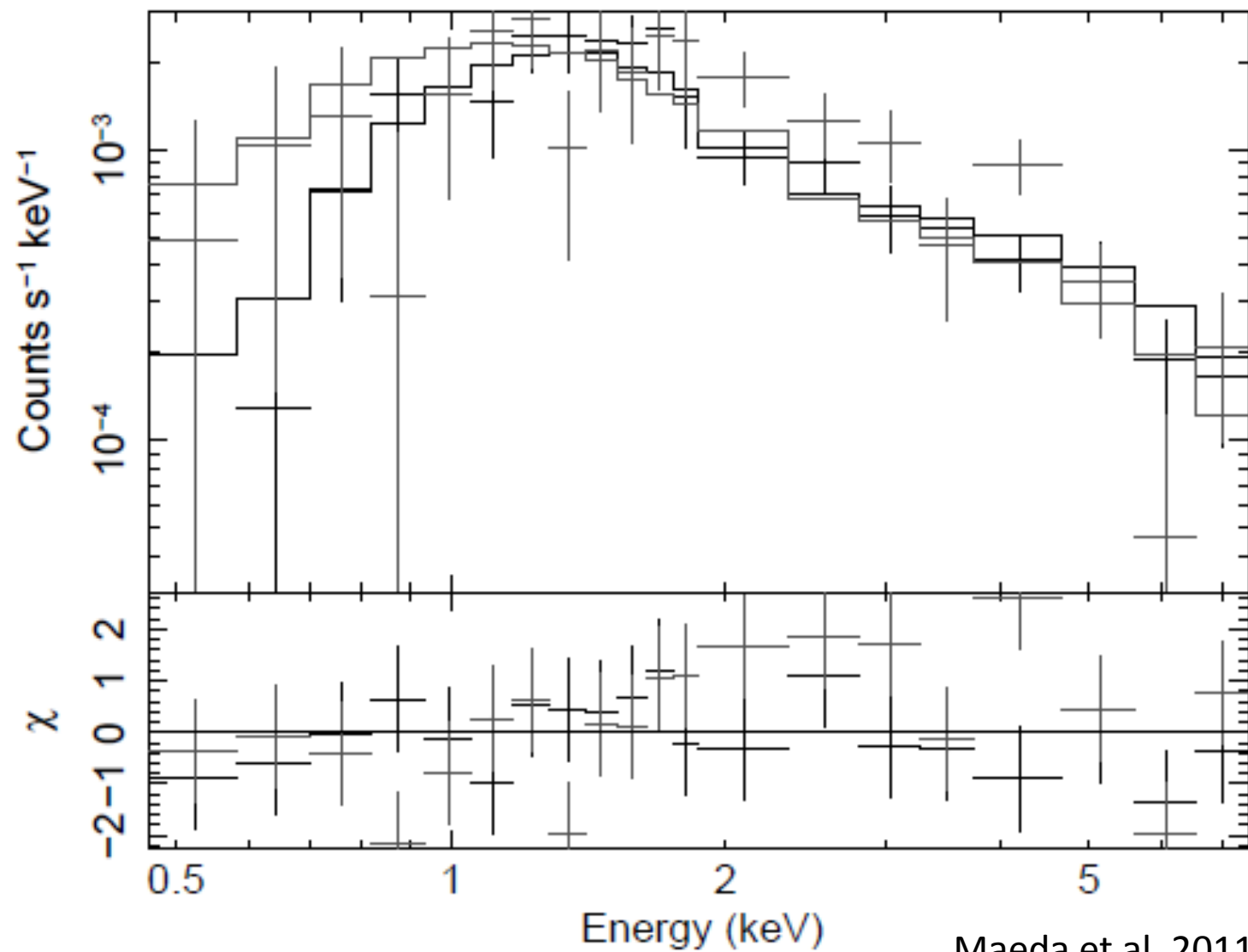
Appendix 6 – Suzaku images

(Subtracted NXB, corrected Exposure and Vignetting)

1FGL J2302.8+4443

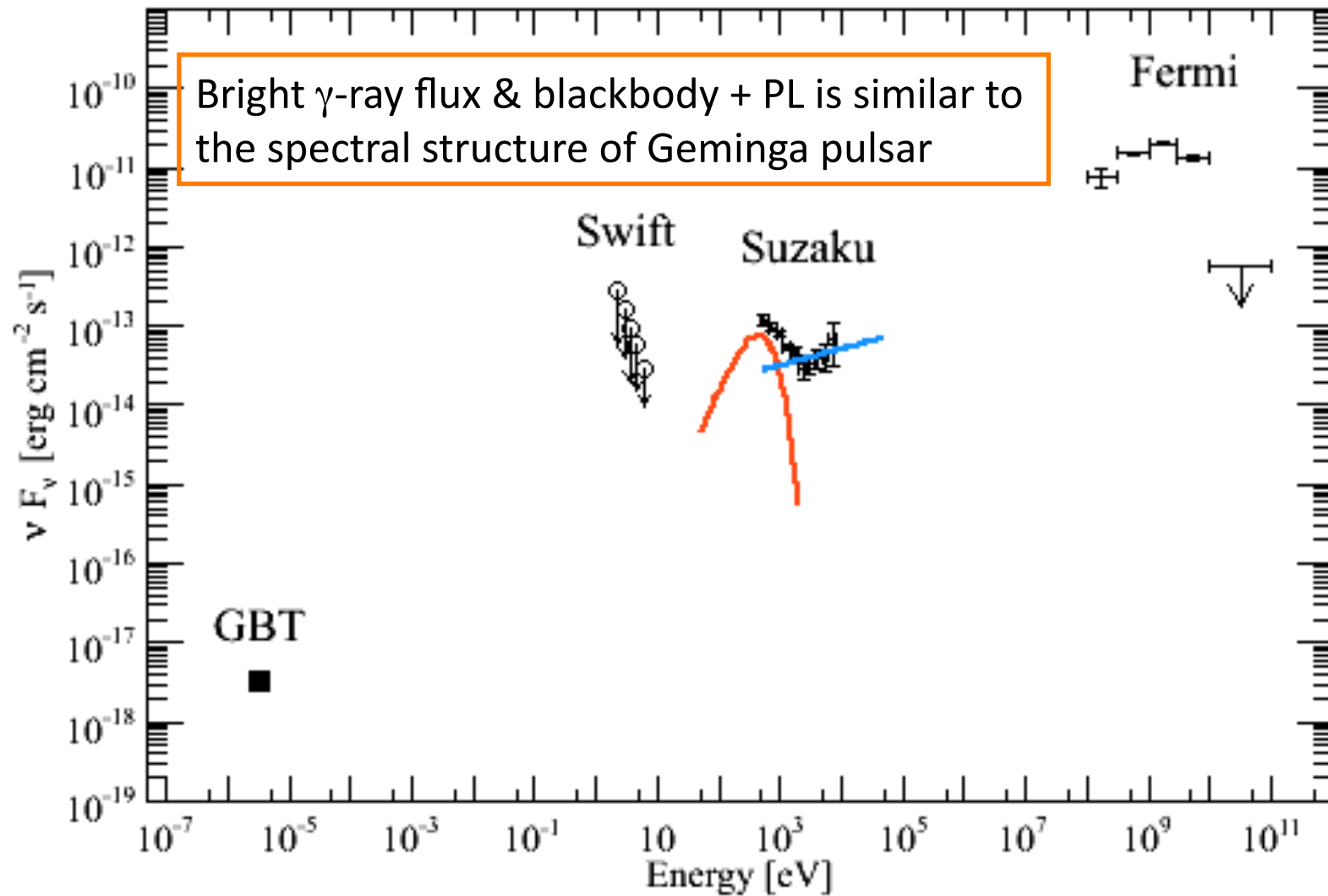


1FGL J1311.7-3429

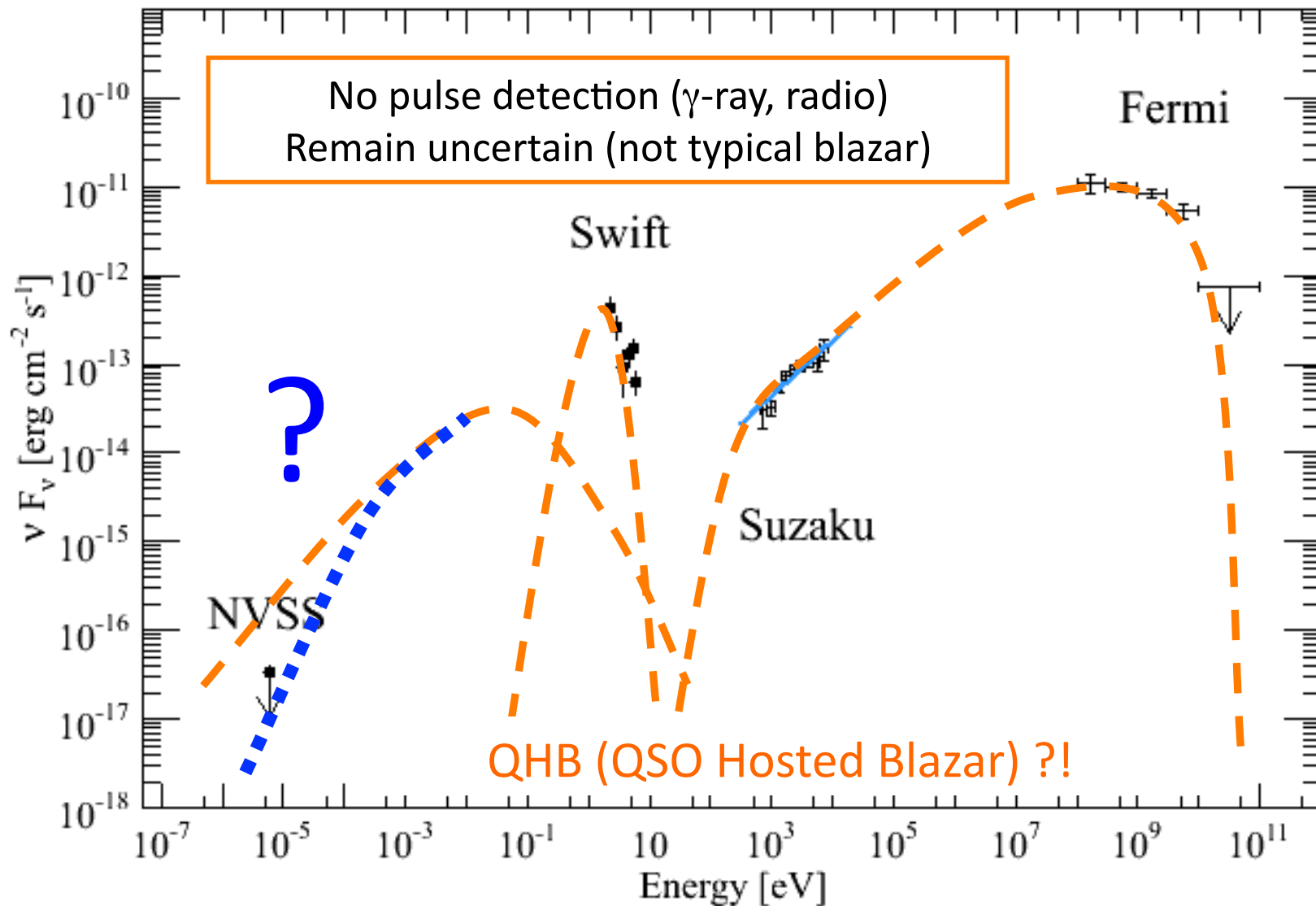


Maeda et al. 2011

1FGL J1231.1-1410

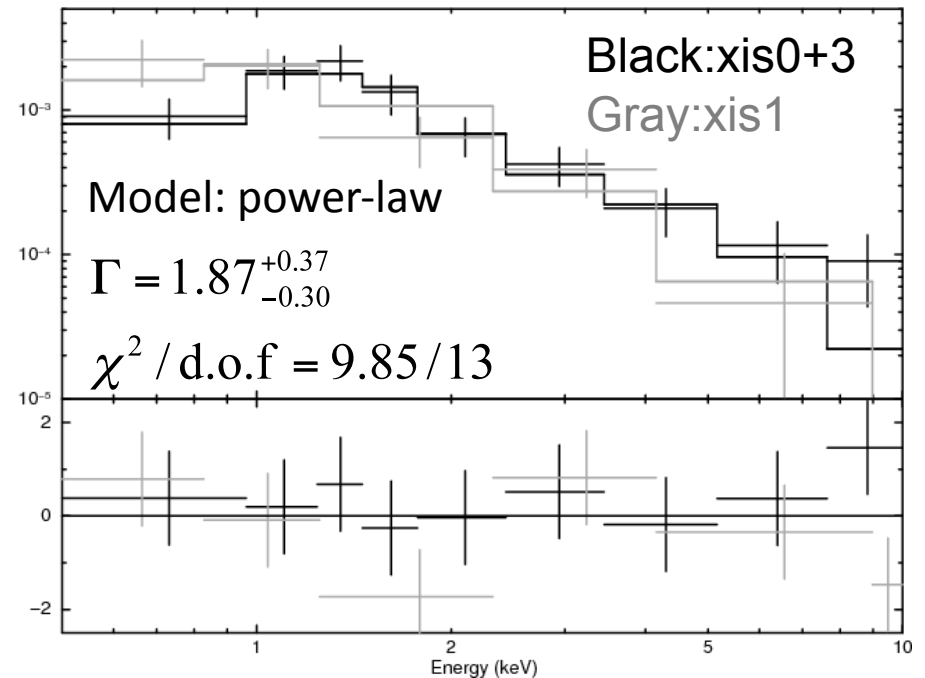
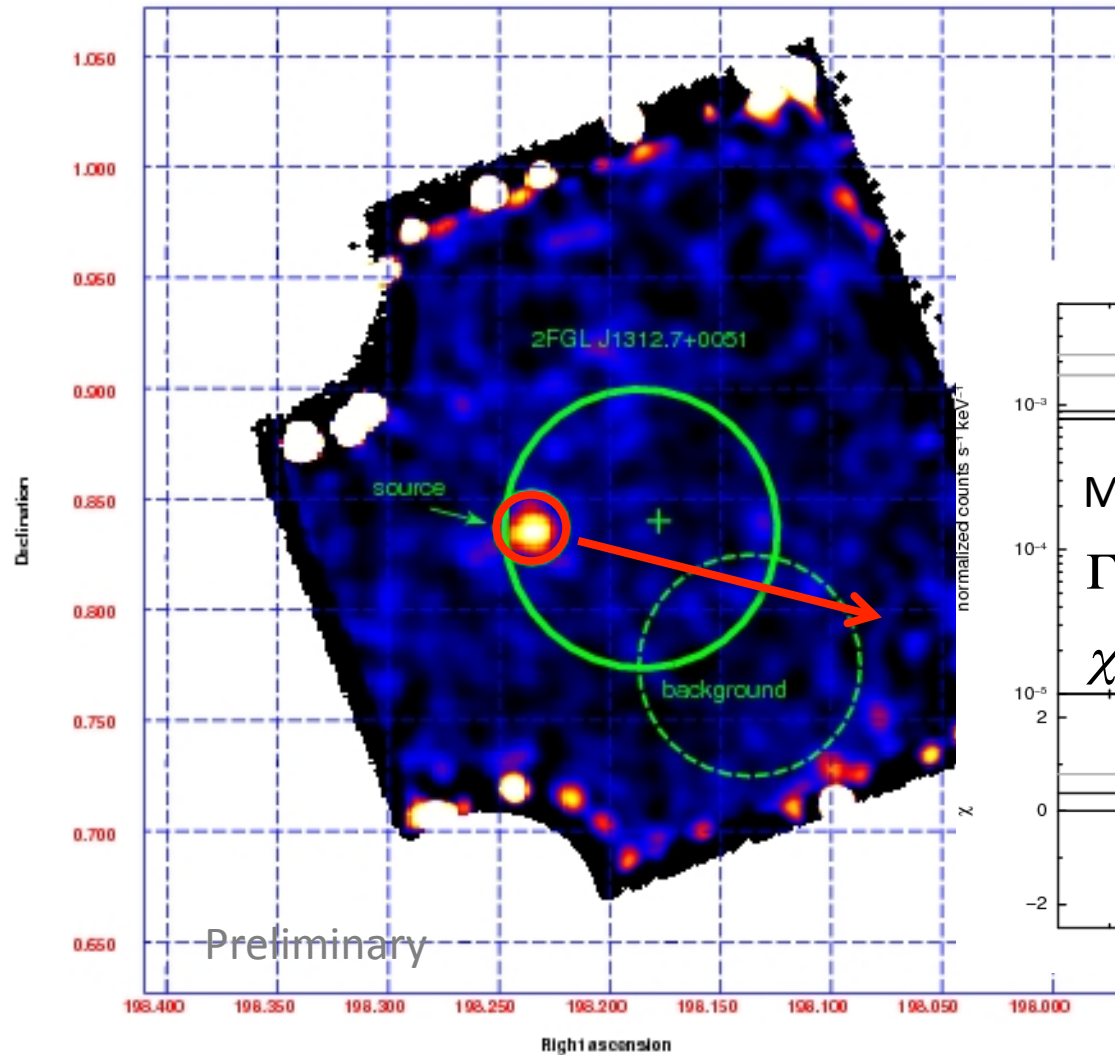


1FGL J1311.7-3429



- 1FGL J1312.6+0048

- One X-ray point source was discovered inside the 2FGL error ellipse



$$F_{2-10\text{keV}} = 8.01^{+2.94}_{-2.63} \times 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}$$

Suzaku/XIS0+3 (0.5-10keV)

(Subtracted NXB, corrected Exposure and Vignetting)